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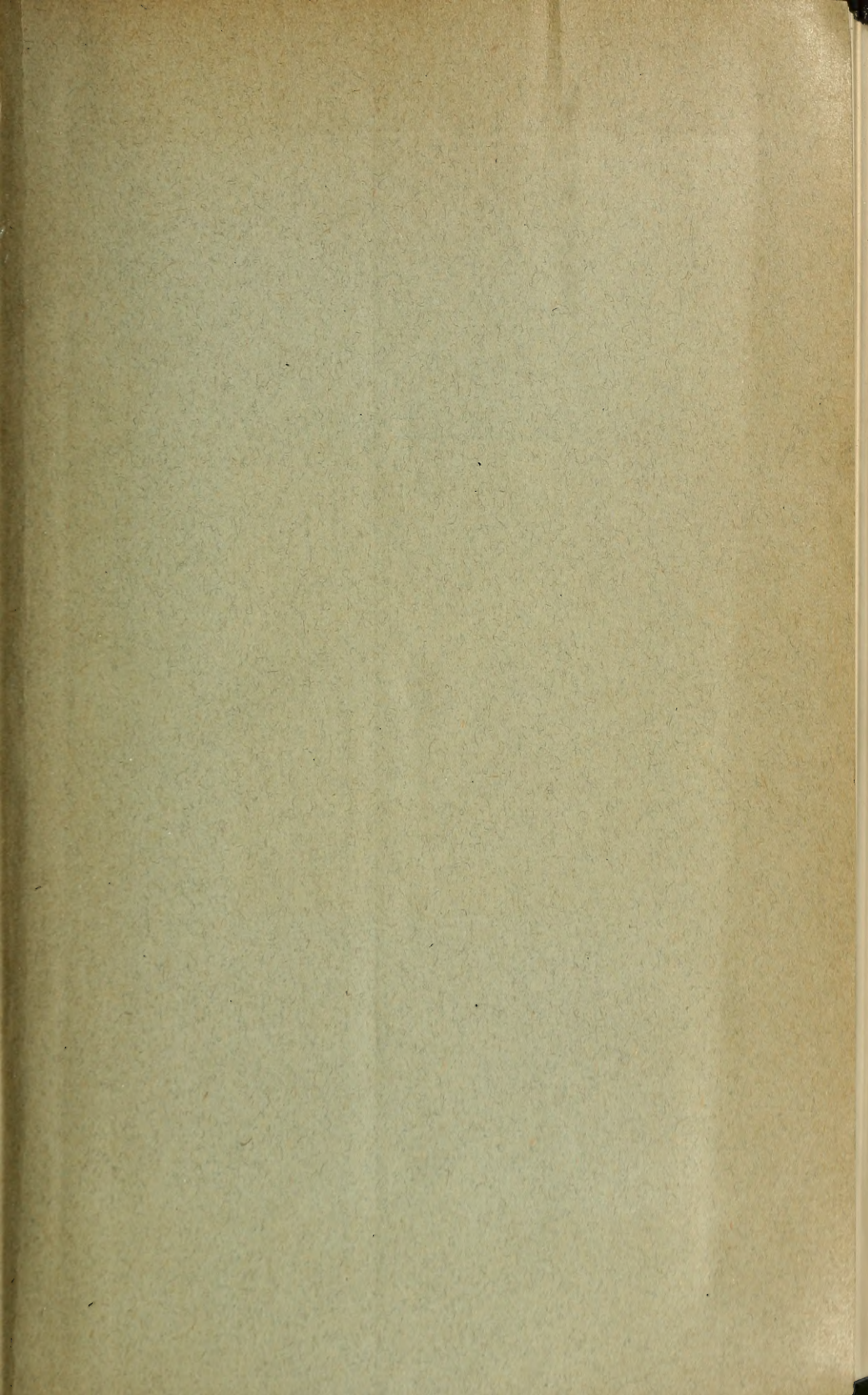
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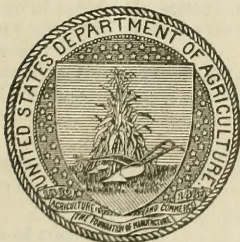
Department Bulletins

Nos. 1051-1075,

63.06(73)

WITH CONTENTS
AND INDEX.

Prepared in the Office of Editorial Work.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1923.

U. S. DEPARTMENT OF AGRICULTURE.



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24-95163 June 13

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1051

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

And the Bureau of Plant Industry

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Washington, D. C.

April 13, 1922

RED CEDAR CHESTS AS PROTECTORS AGAINST MOTH DAMAGE.

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INTRODUCTORY.

Chests made of red cedar have the reputation of protecting clothing stored in them from the ravages of clothes moths. There has been, however, much difference of opinion as to whether the supposed protection comes from the tightness of the chests which excludes moths, or from an inherent quality of the wood that actually kills moths accidentally placed in them with fabrics and furs. Considering the centuries-old belief, entertained among so many peoples, that this odoriferous cedar affords protection against moth attack, surprisingly little has been done to determine whether or not chests made of this wood are efficacious. Working with the southern or webbing clothes moth, *Tineola bisellicella* Hummel (Pl. II, A), the writers undertook a comprehensive study of the effect of red cedar chests upon adults, eggs, and larvæ to ascertain whether or not chests made of red cedar could be considered as adequate protection of clothing against these insects.

SOURCE, DISTRIBUTION, AND DESCRIPTION OF RED CEDAR.

Red cedar (*Juniperus virginiana*), commonly known as Tennessee or Virginia red cedar, is one of the most widely distributed coniferous trees of North America, occurring on dry hills or in deep swamps, sometimes attaining a height of 90 feet, but usually averaging 40 to 50 feet or less. The tree is distributed throughout all sections of the United States as far west as the Rocky Mountains, flourishing under various climatic conditions. It is most abundant, however, in the region from the Ohio River on the north to Florida on the south and from the Atlantic Ocean on the east to Arkansas on the west. In Tennessee, Virginia, and North Carolina the red cedar occurs in large areas of nearly pure forests known as "cedar breaks." In these sections the most extensive manufacture of cedar lumber is conducted.

In general, the red cedar is a straight tree, pyramidal in shape, becoming round-topped in old age, and has a tapering trunk and shreddy bark. The wood is light, close-grained, compact, and durable. The heartwood is red in color and strongly aromatic, while the sapwood is white and devoid of odor.

USES OF RED CEDAR.

The commercial use of the wood dates back to the seventeenth century. In 1632 Morton (12, p. 49-54, pl. 45),¹ in citing the trees that are found in New England, stated:

Cedar, of this sorte there is abundaunce; and this wood was such as Salomon used for the building of that glorious Temple at Hierusalem. . . . This wood cutts red, and is good for bedsteads tables and chests, and may be placed in the Catalogue of Commodities.

In 1682 Gent (4, p. 63), in describing the resources of South Carolina, mentioned the presence in that State of odoriferous and fragrant woods, among them being the sweet-scented cedar and cypress, from both of which were made boxes, chests, tables, and cabinets. He further stated that:

The Dust and Shavings of Cedar, laid amongst Linnen or Woollen, destroys the Moth and all Verminous Insects; It never rots, breeding no worm, by which many other Woods are consumed and destroyed.

In 1757 Peter Kalm (7, p. 264), in a report of his early travels in North America, mentioned red cedar as being prized for its durability.

In 1776 Hunter (6) stated that the timber was very valuable for many uses and possessed a bitter resin which prevented worms from attacking it. Later, in 1786, Lamarek (9) stated that the wood was much sought in America for carpentry, construction of vessels, woodwork, and different utensils, because it was filled with a bitter resin which prevented its destruction by worms. According to Bigelow (1, p. 49-54, pl. 45), in 1820, the wood—

is principally employed for posts in fences, in which capacity it proves more durable than almost any species of wood used for the same purpose.

Loudon (10, p. 848), mentioned *Juniperus virginiana* as producing lumber which is "very odoriferous" and useful for cabinet making

¹ The figures (*italic*) in parentheses refer to "Literature cited," p. 14.

"as it is offensive to most insects." In 1838 he stated (11) that on account of its strength and durability the barriers of the sidewalks of the streets of Philadelphia were made of this wood, which was also used for making tubs, stopcocks, and coffins.

In presenting certain historical data of New York, O'Callaghan (13, p. 40), in all probability referring to red cedar, stated:

There is Red-wood which being burned, smells very agreeable; when men sit by the fire on benches made from it, the whole house is perfumed by it.

Porcher (14, p. 588-589), in 1869, made the statement that—

Cedar boxes are not infested by insects, moths, etc., and are used for storing away woollens. The leaves also prevent the attacks of insects when spread over cloth.

Further reference to the use of red cedar against insects was made by Emerson (3, p. 120) in 1875, to the effect that the agreeable and permanent odor of the wood recommends it for certain uses, such as pencils and the bottoms of boxes and drawers, the aroma making it a safeguard against insects. Similarly, it was stated by Curtis (2, p. 118-119) that boxes and cabinets made of red cedar wood were exempt from insects on account of its odor being offensive to them. Hansen (5, p. 298-299) stated that the wood possessed much economic value, being durable and free from the attacks of insects.

It was reported by Sargent (15) in 1895 that the wood of red cedar is highly resistant to decay and that insects do not molest it. It is further stated by the same author that moths flee from the pungent odor, and that every good housekeeper knows the value of a red cedar chest or a closet lined with this wood. The following year (16) he also asserted that the wood is very fragrant and easily worked, being used largely for fence posts, railway ties, sills, cabinets, lead pencils, the interior finish of houses, and for protecting woollens against the attack of moths.

According to Kent (8) the wood is highly resistant to decay by water and is therefore valuable for fence posts and other purposes where it comes into contact with moist soil or water. This author also states that moths flee from the pungent odor, and that a chest of red cedar or a closet lined with red cedar wood affords an efficient protection against their inroads. It is also reported that the waste at pencil factories is used to manufacture a paper which has been found useful for wrapping wools, furs, and other articles likely to be injured by moths.

It is stated by White (18) that the heartwood of the cedar constitutes the portion of the tree which is used extensively for pencil making. For this purpose it is essential to have the straight-grained red wood, free from knots.

On account of the lack of cedar logs of any great size and the need for the heartwood free from knots, old logs and fence rails are being used for the manufacture of pencil slats.

Within the last 15 years red cedar has been used in constantly increasing quantities in the manufacture of cedar chests. All of the red heartwood and part of the white sapwood is utilized for this purpose. The industry has grown very rapidly and at the present time red cedar chests are recognized as staple articles of furniture. These chests combine ornamental beauty with utility as receptacles for the storage of clothing. Their beautiful and attractive appear-

ance is due to the striations of red heartwood and white sapwood interspersed with the deeper-colored circular or oval knots. By means of the firm construction, the extremely tight-fitting cover, and the heavily-varnished exterior, the odor of the wood is retained within the chest. In this connection it may be of interest to state that during a recent pilgrimage to "The Hermitage," the plantation of Andrew Jackson, located near Nashville, Tenn., in the heart of the red cedar belt, there was seen a hand-made cedar chest which was considerably over a hundred years old. It is reported that this chest still retains the full fragrance or aroma of the cedar, and doubtless from the standpoint of odor still possesses its original efficiency.

AROMA OF RED CEDAR.

The persistent, characteristic odor of red cedar, which has been credited with possessing the property of destroying the clothes moth, or at least preventing damage by it, is due to a volatile oil which forms 1 to 2 per cent of the wood. The pure heartwood, or the red wood, contains from 2 to 4 per cent of this volatile oil, which is pale yellowish-brown in color and possesses an agreeable, persistent odor. The principal constituents of the oil are the alcohol cedrol, or cedrol camphor, which can be separated from the oil in the form of crystals; the sesquiterpene alcohol cedrenol; and the sesquiterpene cedrene. The characteristic odor is probably due to the former two compounds. It is stated that the oil possesses antiseptic properties, but little is known regarding its insecticidal properties.

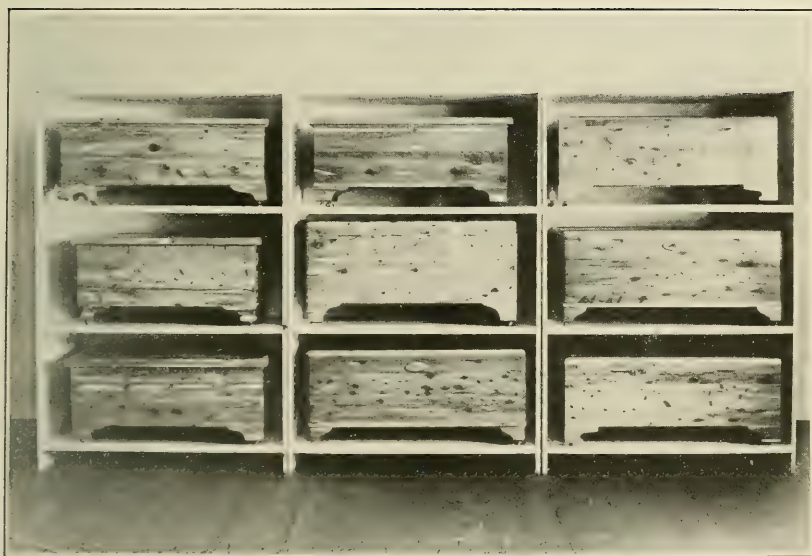
CEDAR CHEST EXPERIMENTS.

The only experimental work previously recorded was by Scott, Abbott, and Dudley, reported (17) upon in 1918. These authors, working with the southern, or webbing, clothes moth (*Tineola biselliella*) and one cedar chest, the history of which was not known, concluded that a red cedar chest killed adults and newly hatched larvæ, but had no effect on larvæ half grown or larger. With these conclusions the writers, working also with *Tineola biselliella*, agree in the main, although none of the chests used by them in their work either killed adult moths or prevented them from laying eggs.

In the experimental work recorded below, nine red cedar chests, with a capacity of from 3.9 to 5.5 cubic feet, were obtained newly made in 1920 from representative manufacturers. These chests (Pl. I) were from regular stock and were shipped direct from the factory. They were of $\frac{3}{4}$ -inch lumber, had the usual attractive finish, and were of the average run of chests placed upon the retail market.

EFFECT UPON ADULT MOTHS.

Scott, Abbott, and Dudley state (17) that 70 adult moths were introduced into a cedar chest and that an examination two months after the last adults were introduced showed that "all had been killed and that no eggs or larvæ were present." This conclusion regarding the effect of a cedar chest upon adult life is not justified since in longevity experiments on file adult clothes moths have never lived two months and seldom so long as 30 days. The same authors state also that 30 adults and a supply of flannel were added to the same chest two years later. Observations made nine weeks after the



NINE CEDAR CHESTS, RANGING IN CAPACITY FROM 3.9 CUBIC FEET TO 5.5 CUBIC FEET, USED IN EXPERIMENTAL WORK.

experiment was started revealed no living adults, no eggs, and no larvæ. In a trunk serving as a check to which the same number of adults were added at the same time, more than 50 live larvæ were counted on the flannel at the close of the experiment. This is the only reference in literature to the effect of cedar chests upon adult clothes moths.

The following data indicate that the cedar chests used by the writers have little practical effect upon the length of life or upon the egg-laying of adult moths. The data are incomplete, but sufficient to prove that adults developing in chests from larvæ transforming to the pupa stage in the chests can live at least 10 days, which in longevity experiments conducted as checks was about the average length of life under normal conditions. It is possible, moreover, for such adults to mate and deposit eggs that will hatch.

On June 17, 1920, 15 adults (sex undetermined) newly emerged in chests were placed with cloth in Chest 1. On June 26, 11 were alive and eggs had been laid. On June 28 all adults were dead, and 123 eggs had been laid; by July 6 all eggs had hatched. Twenty larvæ removed from the chests on June 28 continued to develop normally outside the chest.

On July 2, 1920, 7 adults (sex undetermined) emerging in the laboratory were introduced with cloth into Chest 2. Adults were found depositing eggs on July 3. Examination on July 17 showed 18 eggs had been deposited, 14 having hatched. One adult was barely alive, being too feeble to crawl.

On March 28, 1921, one group of three virgin moths and another group of five, emerging within cedar chests, were placed with cloth in Chest 1. Examination on May 31, 1921, showed all adults dead, and 53 and 30 eggs deposited, respectively. These eggs were infertile and did not hatch.

On March 30, 1921, 6 adults (sex undetermined) found emerged in cedar chests were placed the same day in Chest 2, with cloth. Examination on April 28 showed 1 adult alive, about 80 eggs laid and hatched, and living and dead larvæ.

EFFECT UPON EGGS.

Cedar chests have no apparent effect upon clothes-moth eggs. This is true of eggs deposited in the chests by females emerging in the chests or by females emerging in the laboratory and placed in the chests for oviposition, and of eggs laid outside of chests and later introduced into them. Scott, Abbott, and Dudley (17) state that an examination of a piece of flannel containing many clothes-moth eggs 23 days after it was placed in a cedar chest showed that practically all the eggs were hatched but that the resulting larvæ had died almost immediately. A duplicate test by them gave identical results.

On June 5 and 18, and July 10, 1920, and February 12, March 3, 10, and 28, April 27, May 7 and 14, and June 6, 1921, an average of about 300 eggs, ranging in age from 1 to 7 days, were introduced into each of four cedar chests. Of 50 experiments conducted to determine the effect of chests upon the egg vitality the following 10 are recorded as typical:

(1) Twenty-six adults (sex undetermined) were found March 28, 1921, having developed in cedar chests from larvæ introduced into

the chests January 21, 1921. The adults were placed in a large vial with cloth and immediately replaced in Chest No. 1. Examination May 11 proved that about 200 eggs had been deposited and practically all eggs had hatched.

(2) Four adults (sex undetermined) found in chests April 8, 1921, developed from larvæ introduced into the chests January 1, 1921, were placed with cloth in the chests. Examination April 30 determined that 43 eggs had been deposited and all of them had hatched.

(3) On February 12, 1921, 24, 30, 22, and 14 eggs, deposited, respectively, on February 9-12, 10-12, 11-12, and 12, were placed in Chest 2. Examination on March 2 determined all eggs to have hatched.

(4) On March 10, 1921, 54, 106, 52, 25, and 45 eggs, deposited, respectively, on March 3-5, 5-7, 7-8, 8-9, and 9-10, were placed in Chest 2. Examination on March 17 determined that all eggs had hatched except 46, and of these, 40 were those deposited on March 9-10. Of 292 eggs deposited March 12-14 and held as checks in the laboratory outside of chests, 148 hatched on March 21-22 and 144 on March 22-23. A second examination on March 30 determined all eggs hatched. Of 32 eggs deposited March 2-3 and held as checks in laboratory outside chests, 20 hatched on March 14 (no further observation made).

(5) On April 27, 1921, 232 and 102 eggs deposited April 24-27 and April 26-27, respectively, were placed in Chest 1. Examination on May 11 determined that all eggs had hatched. Of 284 eggs deposited on April 24-27 and held in the laboratory outside of the chests, 100 hatched April 30 and 184 between April 30 and May 3.

(6) On May 14, 1921, 160, 53, 75, 69, 38, and 94 eggs deposited on May 7-9, 9-10, 10-11, 11-12, 12-13, and 13-14, were placed in Chest 3. Examination on May 19 determined that eggs deposited on May 7-11 had hatched; those deposited on May 10-11 were just hatching and the larvæ had not yet had an opportunity to feed. The 69, 38, and 94 eggs deposited between May 11 and 14 were not hatched but were found hatched when examined May 31. Of 336 eggs deposited May 5-6, 1921, and held as checks in the laboratory outside of chests, 111 hatched May 13, 146 on May 14, and 79 on May 18.

(7) On June 6, 1921, 28, 51, 32, 12, and 91 eggs deposited, respectively, on June 1-2, 2-3, 3-4, 4-5, and 5-6, were placed in Chest No. 1. Examination on July 7 determined that all eggs had hatched.

(8) On May 14, 1921, 138, 60, 61, 43, 36, and 19 deposited, respectively, on May 7-9, 9-10, 10-11, 11-12, 12-13, and 13-14, were introduced in Chest No. 1. The eggs were examined on May 17, those deposited on May 7-9 and 9-10 were still hatching, while those deposited between May 11 and 14 were unhatched. Examination made on May 19 determined that all eggs had hatched which were deposited between May 7 and 11 and hatching had begun among those deposited May 11-12. No hatching was noted among eggs deposited May 12-14. Examination on May 31 showed that all eggs had hatched. Of 151 eggs deposited May 16-17 and held as checks in the laboratory outside of chests, 13 hatched on May 24 and 138 on May 25.

(9) On May 7, 1921, 36, 38, and 39 eggs deposited, respectively, on May 4-5, 5-6, and 6-7, were introduced into Chest No. 4. Examination on May 12 determined that eggs deposited on May 4-5 had already hatched, but the larvæ had not yet fed; eggs deposited on

May 5-7 were still unhatched. Examination May 21 determined that all eggs had hatched. Of 739 eggs deposited May 6-7 and held as checks in the laboratory outside of chests, 465 were hatched May 14 and 274 on May 15.

(10) On May 7, 1921, 46, 13, and 107 eggs deposited, respectively, May 4-5, 5-6, and 6-7, were introduced in Chest No. 2. Examination on May 11 determined that 1 egg only of those deposited May 4-5 had hatched. Examination on May 21 showed that all eggs had hatched. Of 267 eggs deposited May 4-5 and held as checks in the laboratory outside of chests, 89 were hatched May 12 and 178 on May 13. Of 336 deposited May 5-6 and held as checks in the laboratory outside of chests, 111 were hatched on July 13, 146 on May 14, and 79 on May 18.

EFFECT UPON LARVÆ.

The effect of cedar chests upon larvæ of clothes moths varies with the age and growth attained by the larvæ when they are subjected to the action of the chests. It has been taken for granted in popular entomological literature that larvæ become fully grown during warm weather in from 4 to 10 weeks, but there are no authentic cases recorded of clothes moths actually reared from egg to adult at any season of the year in less than four months.

Observations made in the laboratory at Washington, D. C., during 1920 and 1921 indicate that no definite statement can be made concerning the time it will take clothes-moth larvæ to become fully grown, since their growth varies tremendously when they are fed upon the same material or upon different materials.

These statements seem necessary to indicate to the reader why one can not judge the age of a clothes-moth larva by its size. Clothes-moth larvæ do not mature as fast as has been thought. It is well to understand that larvæ that have become one-half to full grown, regardless of the time required to attain this growth, have been able to cause so much damage and to leave behind them in their feeding so much webbing (Pl. II, B) and sandlike frass that their presence can be detected by a casual examination of the affected garments. Exception is made of certain fur garments where the feeding larvæ lie buried beneath the fur close to the skin; but even in this case the falling of the severed fur will readily reveal damage.

Garments should not be placed in chests without first having been beaten, brushed, and sunned to remove the larvæ. This treatment, advised as a preliminary for all materials intended for storage in cedar chests, if painstakingly done should remove even younger and smaller larvæ. Any larvæ remaining, however, and entering the chests with the clothing are apt to be very young or very small. This is a most important fact, as cedar chests kill only very young or small larvæ.

Since cedar chests can not be depended upon to kill half to full grown larvæ, such articles as balls of yarn, floor skins backed with woolen cloth, infested pillows stuffed with hair or feathers, and similar articles, all portions of which can not be brushed on all sides, might better be treated by fumigation or other methods to kill older larvæ before being placed in cedar chests. Otherwise these articles may be fed upon somewhat in cedar chests by the older larvæ, until they have transformed into moths, but will be protected thereafter.

CEDAR CHESTS DO NOT KILL ONE-HALF TO FULL GROWN LARVÆ.

Cedar chests can not be depended upon to kill larvæ after they are half to full grown, or after they are about three or four months old. To be sure, many of these older larvæ die in the chests, but it is not possible to tell whether their death is caused by the chests or is the result of the high mortality obtaining among any lot of clothes-moth larvæ used in experimental work. The only work done indicating the effect of cedar chests upon the older larvæ is that of Scott, Abbott, and Dudley (17). They say:

In 1915 flannel was placed in this chest, and 10 one-half to three-fourths grown larvæ were added every two weeks until a total of 60 was reached. Examination made two months after the last addition of larvæ showed 7 live larvæ; 36 larvæ had died and 17 had pupated. Of the 17 pupæ 2 died in the pupa stage and 15 emerged as moths, but died before any eggs were laid. The flannel had been fed upon considerably, but was not badly eaten.

Two years later (1917) this experiment was duplicated by adding 25 one-half to three-fourths grown larvæ at one time and allowing the experiment to run 33 days. The results were almost identical with those of the first experiment.

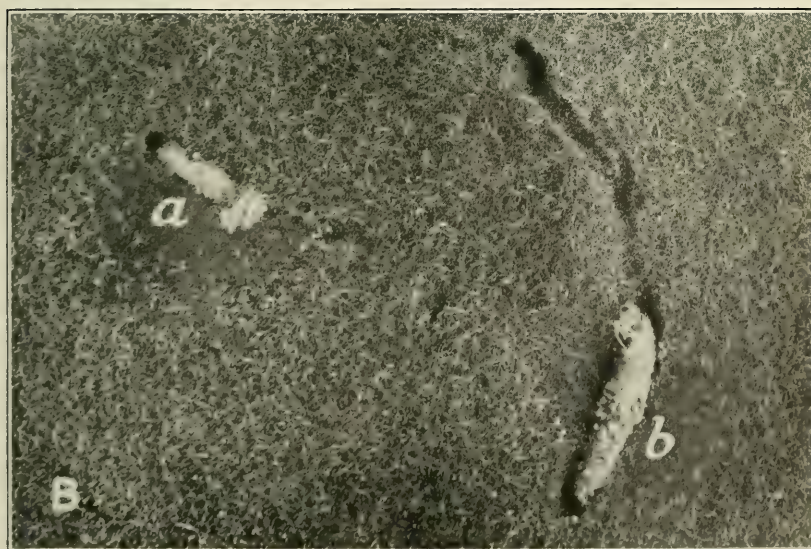
On January 31, 1921, 24 well-grown larvæ were placed in a chest upon a high-grade blue-serge cloth, and 35 others upon a felt pillow top. Both lots of larvæ caused serious damage to the goods by March 2 (Pl. II, fig. 2). During an examination made on that date it was found that of the 50 larvæ 18 were still in the larva stage and alive, 6 had died, 9 had transformed to the pupa stage, and 13 had emerged as adults; the remaining larvæ had eaten through the cloth and escaped into the clothing filling the chest.

Of 100 larvæ (40 well grown, 40 half grown, and 20 very small, but fully four months old) placed on January 31, 1921, in Chest 2 in pill boxes, 13 had emerged as moths by March 2, 16 emerged between March 2 and 17, 19 between March 17 and April 30, and 12 between April 30 and May 11; the remaining 40 died as larvæ or pupæ.

Of 60 well-grown larvæ placed in Chest 1 on January 31, 1921, 2 had transformed to the adult stage by March 2, 9 became adults between March 2 and 17, and 14 between March 17 and May 11; the remaining 35 died either as larvæ or pupæ. Of 50 half to full-grown larvæ placed in Chest 3 on January 31, 13 emerged as adults by March 2. Of the 2, 13, and 13 adults found emerged in Chests 1, 2, and 3 on March 2, developing from larvæ placed in chests on January 31, 1921, 2, 10, and 5, respectively, were alive, while 0, 3, and 8, respectively, were dead.

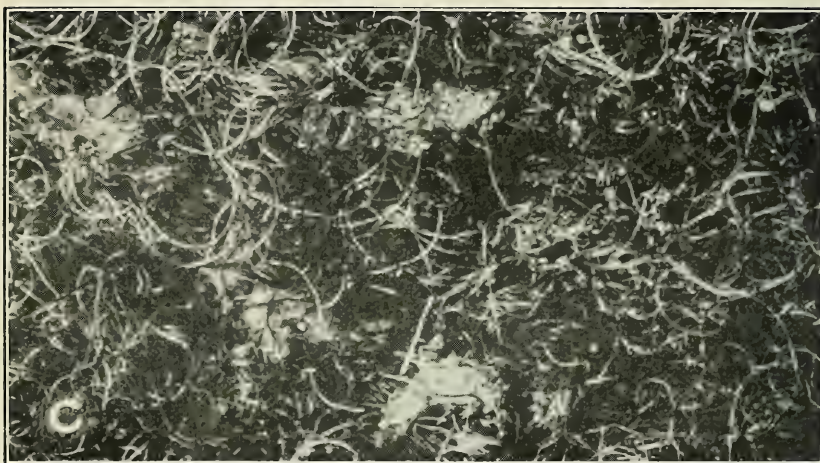
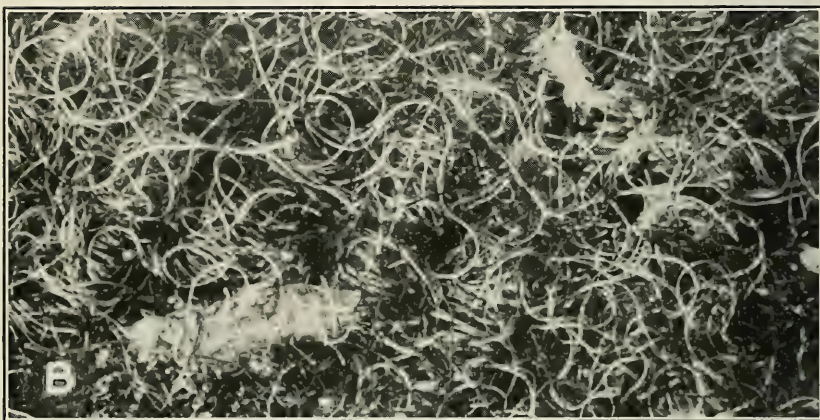
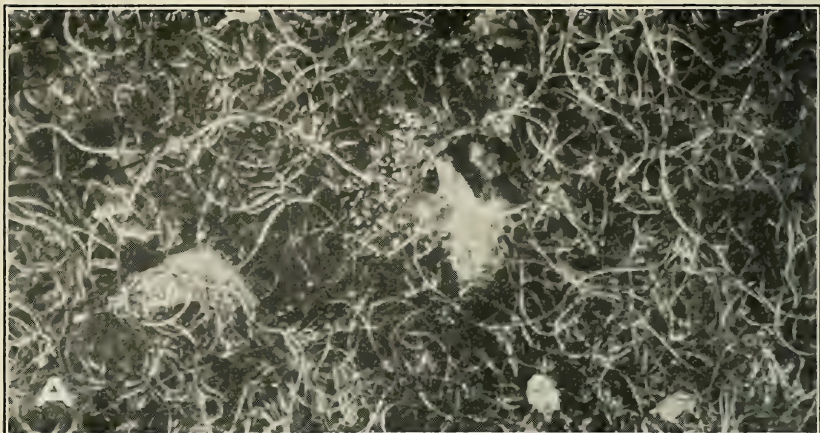
Half to full-grown larvæ placed in Chest 2 on February 11, 1921, developed into adults during the period March 17 to July 27; 1, 1, 8, 6, 4, 3, 7, and 1 being found during examinations made on March 17, 30, April 30, May 11, June 6, July 7, 15, and 27, respectively. The adult found emerged during the July 27 examination, approximately 5½ months after the larvæ were placed in the chest, was alive, very active, and appeared no different in general vitality from others emerging under normal laboratory conditions. One larva of this lot was found alive, normal to all appearances, and very well grown, on July 27, but had died by August 3.

Half to full-grown larvæ placed in Chest 1 on February 11, 1921, developed into adults during the period March 17 to July 23; 1, 8, 3,



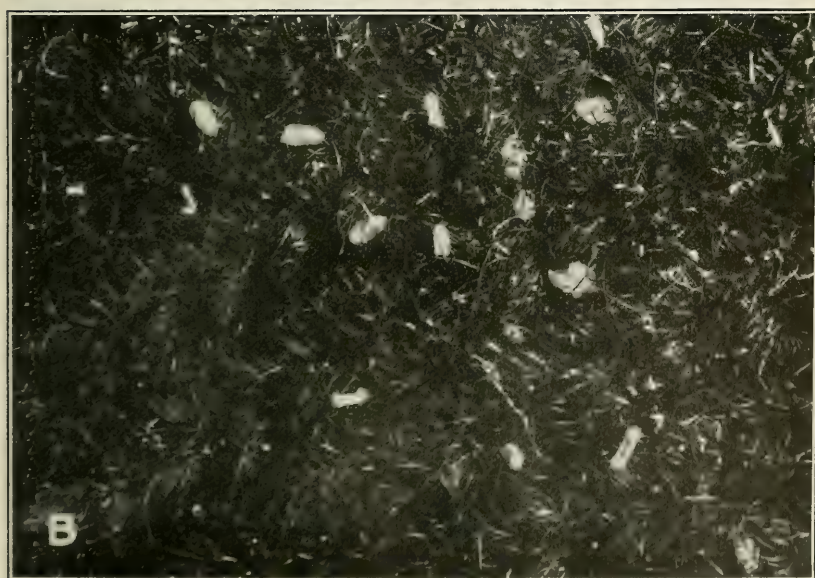
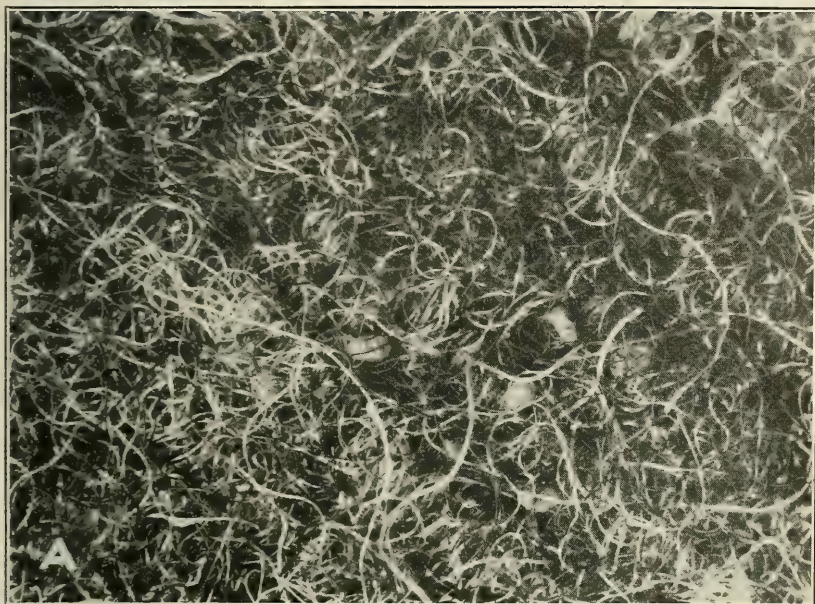
RED CEDAR CHESTS AS PROTECTORS AGAINST MOTH DAMAGE.

A, Adults and well-grown larvæ of *Tineola biselliella*. It is only the larva or worm that damages fabrics. Magnified about 2 diameters. B, Felt pillow top damaged in cedar chest by half to fully grown larvæ of the clothes moth. Beside the damaged portions of goods, note, at *a* and *b*, the whitish tubes of silken threads in which the larvæ secrete themselves while resting. Magnified 2 diameters.



CHEAP GRADE OF ARMY CLOTH SHOWING VARIOUS DEGREES OF WEBBING AND SLIGHT FEEDING BY YOUNG LARVAE OF CLOTHES MOTHS HATCHING INSIDE CHESTS.

The white areas are silken tubes spun by the newly hatched larvæ in which they rest and from the ends of which they feed upon the cloth. A, B, and C represent the maximum amount of webbing ever noted by the authors in any chest. Magnified 12 diameters.



RED CEDAR CHESTS AS PROTECTORS AGAINST MOTH DAMAGE.

A, Eggshells of the clothes moth partially hidden in loosely woven army cloth. Although these eggs have hatched the young larvae were killed in the chest before they could spin webs or feed upon the fabric. Magnified 12 diameters. B, High grade woolen cloth of moderately close weave. Note eggshells and dead newly hatched larvae of clothes moths. Larvae were killed in the chest before they spun webs or fed upon fabric. Magnified about 12 diameters.



WOOLEN CLOTH TAKEN FROM CEDAR CHEST, SHOWING HATCHED EGGS.
DEAD YOUNG LARVAE, AND A VERY SLIGHT WEBBING MADE BY THE
LARVAE BEFORE DEATH.

This sample of cloth, like those of Plate IV, is not injured by the larvæ of the clothes moth.
The circle indicates a dead larva; the arrow, an eggshell.

5, and 2 being found during examinations made March 17, May 11, June 6, July 7, and July 23, respectively.

Half to full-grown larvæ placed in Chest 3 on February 11, 1921, developed as adults during the period March 17 to June 6; 1, 2, 3, 2, and 1 moths being found during the examinations made on March 17, May 12, May 31, June 6, and July 7.

A miscellaneous lot of 100 larvæ, apparently half to full grown, were placed in Chest 1 on April 9, 1921. Examinations made on May 11, May 31, July 7, July 23, and August 3 showed that there had emerged 53, 2, 7, 0, and 0 adults, respectively. Of 100 larvæ of like age placed on April 9, 1921, in Chest 2, 42, 4, 2, 0, 0, and 0 adults were found emerged on April 30, May 11, June 6, July 7, July 23, and August 3, respectively.

CEDAR CHESTS KILL YOUNG LARVÆ.

Cedar chests have a pronounced killing effect upon young clothes-moth larvæ. Of the larvæ hatching within cedar chests from the 2,074 eggs recorded under the discussion of the effect of chests upon the vitality of the eggs, none were found alive during examinations made one month from the date the eggs were placed in the chests. Exception must be made for one larva hatching from eggs laid April 26-27, which were placed in Chest 3 on April 27, 1921, that was found alive during examinations made on May 12, 21, and 31, but which was dead by June 2.

Practically all larvæ hatching within the chests died within two weeks after hatching and a surprisingly large number died within two or three days of hatching. Exact data on this point are lacking because to obtain them would require the chests to be opened so frequently that their killing power would be weakened. Thus Chest 2 had been opened more often than Chests 1, 3, and 4 just previous to May 21 examination recorded in Table I, with the evident result that its effect upon even very young larvæ was quite seriously affected. Scott, Abbott, and Dudley say (17) that larvæ hatching in chests "died almost immediately." As their examination was made 23 days after the eggs were placed in the chest and as their work was done during warm weather, when the egg stage ranges from 4 to 8 days, their statement should be interpreted to mean that the larvæ died without spinning webs or leaving signs of feeding. The practical point to keep in mind is that larvæ hatching within chests did not as a rule feed (Pl. IV and V) upon the cloth, and when they did, the damage done (Pl. III) would not be observed by the average person.

While the statements made concerning larvæ hatching within the chests from eggs placed there can not be as exact as could be wished because of variations in the length of the egg stage, the age of larvæ recorded in Tables I and II is definitely known and can be compared with larvæ accidentally introduced in clothing into chests. These larvæ hatched in the laboratory and were placed in chests at the ages indicated. In these tables are recorded data secured from each of four chests grouped according to the age of the larvæ and the date of examination. The numbers of the chests refer to the same chests in both tables. It will be seen that larvæ hatching outside the chests and later introduced into the chests do not die immediately.

but may linger along for a considerable number of days. Two larvæ, which were 2 days old when placed in a chest, were still alive (Table II) after 31 days in the chest, but were found dead when examined 6 days later. The majority of the very young larvæ die by the end of the first or second week, without causing damage. The greater resistance of the older larvæ is clearly demonstrated by the data. One 2½-month-old larva and one 2-month-old larva survived in the chest for over 2 months. Few people should have occasion to place in chests clothing containing larvæ over 1 month old.

TABLE I.—*Effect of four cedar chests upon 520 larvæ ranging in age from 1 day to 3 months, placed in chests on May 14, 1921.*

Age on entering chest.	Chest No.	Date and result of examinations.											
		May 21.		May 31.		June 6.		July 7.		July 23.		July 27.	
		Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.
3 months.....	1	10	0	6	4	4	6	2	8	0	10	.....	.....
	2	¹ 10	0	6	4	3	7	0	10	.....	.....	.....	.....
	3	10	0	6	4	.....	.....	0	10	.....	.....	.....	.....
	4	10	0	5	5	3	7	0	10	.....	.....	.....	.....
2½ months.....	1	10	0	9	1	8	2	1	9	1	9	0	10
	2	10	0	8	2	7	3	1	9	0	10	.....	.....
	3	10	0	8	2	.....	.....	0	10	.....	.....	.....	.....
	4	10	0	6	4	3	7	0	10	.....	.....	.....	.....
2 months.....	1	10	0	9	1	7	3	0	10	.....	.....	.....	.....
	2	10	0	8	2	7	3	³ 3	7	1	9	0	10
	3	10	0	9	1	8	2	0	10	.....	.....	.....	.....
	4	10	0	10	0	9	1	1	9	0	10	.....	.....
1¾ months.....	1	10	0	9	1	7	3	0	10	.....	.....	.....	.....
	2	10	0	10	0	9	1	⁴ 2	8	0	10	.....	.....
	3	10	0	10	0	8	2	1	9	0	10	.....	.....
	4	10	0	9	1	8	2	0	10	.....	.....	.....	.....
1½ months.....	1	10	0	10	0	10	0	1	9	0	10	.....	.....
	2	10	0	8	2	8	2	3	7	0	10	.....	.....
	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1 month.....	1	10	0	3	7	2	8	0	10	.....	.....	.....	.....
	2	10	0	7	3	5	5	0	10	.....	.....	.....	.....
	3	10	0	6	4	2	8	0	10	.....	.....	.....	.....
	4	10	0	5	5	3	7	0	10	.....	.....	.....	.....
3 weeks.....	1	8	2	3	7	2	8	0	10	.....	.....	.....	.....
	2	10	0	4	6	0	² 10	0	10	.....	.....	.....	.....
	3	9	11	3	17	2	18	0	20	.....	.....	.....	.....
	4	10	0	1	9	0	.....	.....	.....	.....	.....	.....	.....
2 weeks.....	1	0	10	0	10	0	10	.....	.....	.....	.....	.....	.....
	2	10	0	2	8	0	10	.....	.....	.....	.....	.....	.....
	3	8	2	6	4	2	8	0	10	.....	.....	.....	.....
	4	0	10	6	4	0	10	.....	.....	.....	.....	.....	.....
11 days.....	1	2	8	2	8	0	10	.....	.....	.....	.....	.....	.....
	2	10	0	4	6	0	10	.....	.....	.....	.....	.....	.....
	3	3	7	1	9	0	10	.....	.....	.....	.....	.....	.....
	4	6	4	3	7	0	10	.....	.....	.....	.....	.....	.....
8 days.....	1	1	9	0	10	.....	.....	.....	.....	.....	.....	.....	.....
	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8	2	2	8	0	10	.....	.....	.....	.....	.....	.....
	4	7	3	2	8	0	10	.....	.....	.....	.....	.....	.....
3 days.....	1	0	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	20	0	2	18	0	20	.....	.....	.....	.....	.....	.....
	3	3	7	0	10	.....	.....	.....	.....	.....	.....	.....	.....
	4	4	6	0	10	.....	.....	.....	.....	.....	.....	.....	.....
2 days.....	1	0	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	20	0	1	19	0	20	.....	.....	.....	.....	.....	.....
	3	5	5	0	10	.....	.....	.....	.....	.....	.....	.....	.....
	4	4	6	1	9	0	10	.....	.....	.....	.....	.....	.....
1 day.....	1	0	8	0	10	.....	.....	.....	.....	.....	.....	.....	.....
	2	10	0	0	10	.....	.....	.....	.....	.....	.....	.....	.....
	3	.....	.....	0	10	.....	.....	.....	.....	.....	.....	.....	.....
	4	.....	.....	2	8	0	10	.....	.....	.....	.....	.....	.....

¹ Examination made May 7, 1921, showed no mortality among larvæ placed in chests Apr. 30.

² Thoroughly active and normal.

³ Alive but on point of death.

⁴ Larvæ doubtfully dead.

TABLE II.—Effect of four cedar chests upon 520 larvæ ranging in age from 1 to 28 days, placed in chests Apr. 30, 1921.

Age on entering chest.	Chest No.	Date and result of examinations.									
		May 11.		May 21.		May 31.		June 6.		July 7.	
		Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.
<i>Days.</i>											
28.....	1	5	5	2	8	1	9	1	9	0	10
	2	3	7	1	9	0	10				
	3	3	7	2	8	0	10				
	4	6	4	6	4	3	7	3	7	0	10
21.....	1	6	4	5	5	1	9	0	10		
	2	8	2	2	7	0	10				
	3	8	2	3	7	1	9	0	10		
	4	8	2	8	3	3	7	3	7	0	10
14.....	1	6	4	2	8	2	8	1	9	0	10
	2	6	4	1	9	0	10				
	3	3	7	1	9	0	10				
	4	5	5	1	9	0	10				
11.....	1	7	3	2	8	0	10				
	2	5	5	1	9	0	10				
	3	9	1	1	9	1	9	0	10		
	4	6	4	2	8	0	10				
10.....	1	8	2	2	8	0	10				
	2	4	6	0	10						
	3	6	4	3	7	0	10				
	4	6	4	2	8	0	10				
9.....	1	3	7	1	9	1	9	0	10		
	2	8	2	3	7	1	9	0	10		
	3	5	5	1	9	0	10				
	4	8	2	5	5	0	10				
8.....	1	2	8	0	10						
	2	4	6	1	9	0	10				
	3	4	6	2	8	0	10				
	4	5	5	5	5	0	10				
7.....	1	5	5	1	9	0	10				
	2	6	4	1	9	1	9	1	9	0	10
	3	6	4	2	8	0	10				
	4	3	7	0	10						
5.....	1	1	9	1	9	1	9	1	9	0	10
	2	6	4	2	8	0	10				
	3	6	4	4	6	0	10				
	4	6	4	3	7	0	10				
4.....	1	3	7	1	9	0	10				
	2	6	4	4	6	0	10				
	3	2	8	0	10						
	4	4	6	0	10						
3.....	1	3	7	0	10						
	2	6	4	2	8	0	10				
	3	5	5	² 3	7	0	10				
	4	3	7	0	10						
2.....	1	3	7	1	9	0	10				
	2	6	4	¹ 1	9	0	10				
	3	7	3	² 3	7	1	9	0	10		
	4	4	6	1	9	1	9	0	10		
1.....	1	4	6	0	10	0	10				
	2	6	4	1	9	0	10				
	3	4	6	² 1	9	0	10				
	4	7	3	0	10						

¹ Very active and normal in appearance.² Larvæ inactive and doubtfully alive.

CONCLUSIONS.

Chests made of heartwood of red cedar (*Juniperus virginiana*), such as are found on the market, if in good condition as regards tightness, are effective in protecting fabrics from clothes-moth attack if certain precautions are taken to beat, brush, and, when possible, sun articles before placing them in the chest. The writers experimented with chests from the time of manufacture until they were 1 year old, and believe that chests will retain indefinitely their value as protectors against moth ravages provided they are cared for

properly. Since it is the odor of red cedar which is effective against moths it is recommended that in using cedar chests for the protection of clothing, fabrics, and furs, special care should be taken to prevent undue escape of the aroma from the chests. *The chests should remain tightly closed except when clothing is being removed or placed in them, and this procedure should be accomplished as rapidly as possible.* Aside from their value in killing moths, cedar chests are so tightly constructed that adult moths can not gain access to them except when they are open. This is not true of the average trunk or other receptacle in which clothing is stored.

Cedar chests exert no noticeable effect upon the adult moth or miller, the parent insect, which does no damage to clothing but which may lay eggs from which hatch the destructive larvæ, or worms. Moths that run or fly into chests, when open, may live as long as two weeks or even a month, and lay many fertile eggs.

Further, cedar chests are not effective against eggs, no matter whether the eggs are laid outside of the chest and accidentally introduced with the clothing, or whether they are laid in the chest itself. This is true regardless of the age of the eggs when they are subjected to the action of the chest. Imprisonment of adult moths and eggs in a cedar chest, however, is not an important consideration since the young larvæ promptly succumb to the effect of the chest and neither the moth nor the egg eats. However, cedar chests can not be depended upon to kill larvæ after they are 3 or 4 months old, or are from one-half to full grown. Some of the half to full-grown larvæ placed in chests have died, but their death may have been due to a normal mortality. The practical consideration is that many of them were not killed, but continued their development and matured as adults. These larger larvæ are capable of doing considerable damage within the chests though it is believed that their activities are somewhat retarded by the effect of the chests. The older the larvæ when they enter the chest the more resistant they are to this, until finally an age or size, not easily defined, is attained when larvæ are capable of withstanding chests and continue their feeding and development.

Cedar chests do kill young larvæ.—Larvæ hatching from eggs within the chests die in most instances within two or three days, and practically all die within two weeks. Larvæ hatching from eggs outside the chests and introduced into them in clothing do not die so quickly as larvæ hatching inside the chests because they are older, but the majority of such larvæ, which soon show a tendency not to feed, die during the first and second weeks, although some may live longer. Two larvæ, 2 days old when placed in a chest, lived for about 35 days; such resistance, however, is the exception rather than the rule.

It is important that articles intended for storage in cedar chests should be most painstakingly cleaned, beaten, brushed, and sunned whenever practicable to remove or kill as many of the moth eggs and larvæ as possible. Special attention should be given to brushing all seams, creases, and pockets. Clothing thoroughly brushed and sunned should harbor none of the larger or older moth larvæ and very few, if any, eggs and young larvæ. Such clothing if stored at once in good cedar chests should be protected from moth ravages,

for the young larvæ that might be present, or those that might hatch from eggs present in the clothing, would be killed before they could cause serious damage.

Although cedar chests may be regarded as protectors against clothes moths, attention is called to the fact that a chest of ordinary wood, if as tightly constructed, would be just as effective, provided the clothing were as thoroughly cleaned, brushed, and sunned, and from 1 to 2 pounds of good grade naphthalene were packed within.

Woolen garments freshly cleaned and thoroughly brushed will be well protected if tightly wrapped with naphthalene in several thicknesses of ordinary paper. Many persons protect their clothing by carefully cleaning and brushing just before wrapping in paper. In wrapping with paper special attention should be given to turning back the paper at the ends of the bundle that no opportunity to gain access be left for the moths.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1052



Contribution from the Bureau of Chemistry
W. G. CAMPBELL, Acting Chief

Washington, D. C.



March 13, 1922

RATIONS FOR FEEDING POULTRY IN THE PACK- ING HOUSE.

[From the Food Research Laboratory.¹]

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PURPOSE OF INVESTIGATION.

Poultry fleshing or finishing is rapidly becoming a very important specialized phase of the poultry industry of the United States. It does not seem to be feasible to fatten poultry extensively on the farm for the reason that dressed poultry, being highly perishable, requires chilling and holding, the facilities for which the farmer ordinarily lacks. Moreover, the shrinkage in weight which occurs when the fattened birds are shipped alive from the farm to the packing house usually offsets the gain obtained during the fleshing period. As practiced in the modern poultry-packing plant, fleshing may be considered a manufacturing process whereby the range birds received by the packer are put in condition for the market. This is accomplished by intensive feeding for a period of from 7 to 14 days, followed by dressing, chilling, grading, and packing.

The twofold object of fleshing poultry is to add a substantial amount of flesh to the fowls and to improve the quality of the edible portion. The finishing process adds weight to the edible parts more rapidly than to the inedible parts, thus increasing the value of such poultry to the consumer. The producer's gain lies in the fact that the

¹ This bulletin was compiled by J. S. Hepburn, junior chemist, and R. C. Holder, assistant chemist, under the direction of H. A. McAleer, chief, and M. E. Pennington, formerly chief, Food Research Laboratory. The chemical part of the investigation, which covered a period of four years, was done by A. W. Broomell, A. D. Greenlee, J. S. Hepburn, R. C. Holder, E. F. Kohman, H. A. Shonle, and G. C. Swan. The feeding work was done by H. C. Bowman, J. M. Borders, R. L. Cochran, L. E. Harker, A. C. Kilgman, P. L. Sanford, H. L. Shrader, C. E. Sidler, R. J. Skinner, and P. S. White. D. C. Kennard assisted in the compilation of the data here reported.

packer buys the surplus of this seasonal product when it is available, puts it in condition for the market, and holds it in cold storage until needed.

The ration and methods of feeding must be designed to accomplish the desired results. For instance, the kind of ration and length of feeding period should vary with the age and class of the birds. In order to secure such information, poultry-fleshing experiments were begun by the Food Research Laboratory in 1916. In connection with these experiments, data on the losses due to dressing, such as blood, feathers, and offal, and on the loss caused by chilling were secured. Representative lots of birds were selected before and after feeding for dissection into their edible and inedible components. Chemical analyses of the various edible portions were made to determine the composition of the range or unfattened birds as compared with that of similar birds after fleshing.

METHODS OF PROCEDURE.

Two types of experiments were conducted:

(1) *Twelve-bird experiments.*—The metal batteries, commonly used in poultry-feeding houses, were partitioned into individual compartments, 12 by 18 inches. Each bird was supplied with an individual cup so constructed as to eliminate all possible waste of feed. Thus an accurate record of each bird's feed consumption was obtained. As far as possible all variations in size and vigor of the birds were eliminated, so that the results indicate the effects of the rations on normal birds, rather than the gains which can be made with the rations fed under packing-house conditions. The birds were fed twice daily, at 8 a. m. and at 4 p. m. Each was weighed at the beginning of the experiment, and again on the fourth, eighth, eleventh, and fourteenth day. After selection, the birds were held for a preliminary period of 24 hours, during which time they received only a light feed of corn meal and buttermilk, in order that the contents of their digestive tracts might be uniform at the beginning of the experiment. In conformity with the usual practice, they were fed sparingly for the first three days, the amount of feed being gradually increased to full feed according to their desire until about the sixth day. As the object at all times was to maintain a keen appetite, any feed remaining at the end of 20 or 30 minutes was removed. At the time of feeding, an experimental ration, consisting of corn meal (40 parts) and buttermilk (60 parts), was fed to similar birds selected as controls. The results secured with each experimental ration were compared directly with those secured with the control ration. The efficiency of the ration fed to the control was given the value of 100, and the values of the experimental

rations were calculated. In this way the variations resulting from differences in the weather, the physical condition of the birds, etc., were reduced.

(2) *Battery experiments*.—The second series of experiments was conducted with a larger number of birds fed in batteries under packing-house conditions. Instead of securing the individual weights or feed consumption data, the total weight of the birds and their total feed consumption were recorded and the average gain and feed consumed by each bird calculated. Except that the control ration of corn meal and buttermilk was not always fed with the experimental rations, the methods were practically the same as those employed in the 12-bird experiments.

In the small-scale experiments, dressing and chilling records on different classes of birds were kept, to show the losses occurring before and after feeding. The weights of the birds were recorded just before slaughter, after killing, and after cooling in a mechanically refrigerated chill room for 24 hours. These birds were then dissected into meat, skin, edible organs, crude gizzard fat, offal, and bones. Thus records were obtained of the edible and inedible portions of the different classes before and after feeding. The edible parts were analyzed for their moisture, fat, and protein content.

RESULTS OF INVESTIGATION.

Table 1 shows the composition of the various poultry feeds employed in these experiments. The results of the experimental work are given in Tables 2 to 16, inclusive. In the battery experiments all weights were obtained and recorded in avoirdupois units. In the 12-bird experiments the weights were obtained in metric units of weight (grams), but, for the convenience of the reader, they are recorded in avoirdupois units (pounds or ounces). Percentage figures in the tables giving data on the 12-bird experiments were calculated from the original weights expressed in grams.

TABLE 1.—*Composition of poultry feeds used.*

Feeds.	Protein.	Fat.	Carbohydrates.		Ash.	Water.	Solids.
			Nitrogen-free extract.	Fiber.			
Cereal grains and by-products:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Barley, whole ground.....	12.31	3.00	61.53	7.33	5.79	9.99	90.01
Corn meal.....	8.94	4.48	70.91	2.71	1.26	11.70	88.30
Oats, whole ground.....	10.86	5.96	55.73	15.12	3.36	8.97	91.03
Oatmeal.....	15.90	6.60	65.80	1.70	2.10	7.80	92.20
Oat middlings.....	16.38	7.84	59.80	2.31	2.53	11.14	88.86
Oat flour.....	16.19	7.32	65.92	1.58	1.30	7.69	92.31
Oats, rolled.....	16.31	6.64	65.94	1.01	2.05	8.05	91.95
Rice polish.....	12.06	12.21	43.32	12.19	11.96	8.26	91.74
Rice bran.....	13.74	12.46	56.87	2.19	5.78	8.96	91.04
Wheat, whole ground.....	12.20	2.00	71.50	2.00	1.90	10.20	89.80
Wheat, low-grade flour.....	19.94	5.07	59.34	5.07	3.33	9.96	90.04
Wheat, standard middlings	17.00	6.04	55.83	6.73	3.96	10.44	89.56
Oil-bearing seed by-products:							
Coconut meal.....	19.56	8.65	45.71	9.78	7.52	8.78	91.22
Peanut flour.....	44.34	9.12	29.74	4.16	4.45	8.19	91.81
Peanut meal with hulls.....	22.31	5.56	25.11	37.03	3.18	6.81	93.19
Rapeseed meal.....	26.00	11.50	42.73	8.05	5.36	6.36	93.64
Soy-bean meal.....	42.75	7.95	30.20	5.27	5.66	8.17	91.85
Grain sorghums:							
Kafir ¹	11.10	3.00	70.10	2.30	1.70	11.80	88.20
Milo, whole ground ¹	10.70	2.00	70.50	2.40	2.80	10.70	89.30
Roughage:							
Alfalfa.....	12.81	1.85	34.25	32.51	10.04	8.54	91.46
Animal products:							
Meat scrap.....	51.62	9.69	6.52	2.26	21.96	7.95	92.05
Buttermilk, natural.....	3.50	.40	4.35	.....	.75	91.00	9.00
Buttermilk, semisolid.....	11.88	2.20	11.23	.....	3.31	71.38	28.62
Buttermilk, powdered.....	33.32	3.26	41.33	.....	14.35	7.74	92.26

¹ Analyses taken from Henry and Morrison, "Feeds and Feeding," p. 635, published by the Henry Morrison Co., 1917.

TABLE 2.—Results of fleshing broilers (12-bird experiments).

Ration.					Initial weight. ¹	Gain.		Relative gain. ²	Feed per pound gain, experimental ration.	
No.	Special feeds.	Corn meal.	Butter-milk.	Experimental ration.		Control ration.				
		Per cent.	Percent.	Percent.	Lbs.	Lbs.	Per cent.	Percent.	Lbs.	
1	Peanut meal.....	8.33	25.00	66.67	{ 1.9 1.7	{ 0.61 .56	{ 32.09 32.87	{ 24.92 35.58	{ 129 92	{ 2.81 3.42
2	Peanut meal.....	10.00	20.00	70.00	{ 1.4 2.1	{ .67 .83	{ 47.85 39.61	{ 30.10 32.92	{ 159 120	{ 2.64 2.55
3	Peanut meal.....	10.00	23.33	66.67	{ 1.7 1.8	{ .64 .80	{ 37.76 44.25	{ 25.28 33.47	{ 149 132	{ 3.03 3.45
4	{ Peanut meal..... Rice bran.....	{ 5.00 5.00	{ 23.33	{ 66.67	{ 1.8 1.3	{ .78 .55	{ 43.60 42.65	{ 33.47 35.08	{ 130 122	{ 2.63 2.83
5	{ Peanut meal..... Low-grade flour..... Rice bran.....	{ 7.50 3.00 1.50	{ 18.00	{ 70.00	{ 1.4 2.1	{ .72 .85	{ 51.39 40.29	{ 30.10 32.92	{ 171 122	{ 2.47 2.48
6	{ Peanut meal..... Low-grade flour..... Rice bran.....	{ 9.00 4.50 4.50	{ 12.00	{ 70.00	{ 1.4 2.1	{ .66 .70	{ 47.49 33.19	{ 30.10 32.92	{ 158 101	{ 2.65 2.82
7	{ Peanut meal..... Low-grade flour..... Middlings (standard wheat).....	{ 7.50 3.00 4.50	{ 15.00	{ 70.00	{ 1.9 1.9 2.2	{ .75 .95 1.20	{ 39.30 49.93 53.05	{ 35.73 35.73 44.20	{ 110 140 120	{ 3.05 2.64 2.27
8	{ Peanut meal..... Low-grade flour..... Middlings (standard wheat).....	{ 9.00 3.00 3.00	{ 15.00	{ 70.00	{ 1.4 2.1	{ .82 .77	{ 58.92 36.82	{ 30.10 32.92	{ 196 112	{ 2.27 2.70
9	Coconut meal.....	5.00	28.33	66.67	{ 2.0 2.3 1.9	{ .44 .73 .76	{ 22.08 31.95 39.96	{ 16.51 28.15 36.10	{ 134 113 111	{ 3.38 3.05 2.94
10	Coconut meal.....	8.33	25.00	66.67	{ 2.0 2.3 1.9	{ .40 .84 .69	{ 19.88 36.49 36.42	{ 16.51 28.18 36.10	{ 120 129 101	{ 3.34 2.85 3.07
11	Coconut meal.....	13.33	20.00	66.67	{ 2.0 2.4 1.9	{ .28 .51 .53	{ 13.78 21.38 27.78	{ 16.51 28.18 36.10	{ 83 76 77	{ 4.50 3.92 3.58
12	Soy-bean meal.....	8.33	25.00	66.67	{ 1.6 2.0 2.2 1.7	{ .86 .57 .80 .58	{ 54.04 28.85 36.47 34.34	{ 49.05 16.51 28.18 35.58	{ 110 174 129 97	{ 2.19 2.66 2.62 3.12
13	{ Soy-bean meal..... Meat scrap..... Water.....	{ 6.67 1.67 60.00	{ 25.00	{ 6.67	{ 2.0 2.2	{ .46 .55	{ 23.10 24.94	{ 16.51 28.18	{ 140 89	{ 3.44 4.14
14	Rapeseed meal.....	5.00	28.33	66.67	{ 1.9 2.4	{ .36 .55	{ 18.96 22.90	{ 24.92 20.23	{ 76 113	{ 4.08 3.08
15	Rapeseed meal.....	8.33	25.00	66.67	{ 1.9 2.5	{ .38 .34	{ 19.91 13.79	{ 24.92 20.23	{ 80 68	{ 3.94 4.49
16	Rice bran.....	10.00	23.33	66.67	{ 1.8 1.3	{ .60 .48	{ 33.31 36.82	{ 33.47 35.08	{ 100 105	{ 3.16 3.36
17	{ Rice bran..... Alfalfa meal.....	{ 10.00 3.33	{ 20.00	{ 66.67	{ 1.8 1.3	{ .62 .48	{ 34.56 36.60	{ 33.47 35.08	{ 103 104	{ 3.32 3.33
18	{ Rice bran..... Meat scrap.....	{ 10.00 3.33	{ 20.00	{ 66.67	{ 1.8 1.3	{ .69 .51	{ 38.12 38.90	{ 33.47 35.08	{ 114 111	{ 2.90 3.19
19	{ Low-grade flour..... Middlings (standard wheat)..... Peanut flour.....	{ 3.00 6.00 6.00	{ 15.00	{ 70.00	{ 2.1 1.9 1.9	{ 1.16 .74 .74	{ 55.30 38.72 39.03	{ 44.20 35.73 35.73	{ 125 108 109	{ 2.09 2.73 2.85
20	Kafir meal.....	40.00	.....	60.00	{ 1.7 1.8	{ .38 .52	{ 22.61 29.02	{ 29.55 32.17	{ 77 90	{ 4.79 3.44

¹ Average per bird.² Control taken as 100 per cent.

TABLE 3.—*Results of fleshing broilers (battery experiments).*

Ration. ¹					Number of birds.	Days fed.	Initial weight.	Gain.			Relative gain. ²
No.	Special feeds.		Corn meal.	Butter-milk.				Experimental ration.	Control ration.		
1	Peanut meal.....	Per ct. 8.33	Per ct. 25.00	Per ct. 66.67	52	14	Lbs. 1.83	Lbs. 0.27	Per ct. 14.75	Per ct. 18.09	Per ct. 82
2	Peanut meal.....	10.00	23.33	66.67	40	8	1.58	.55	34.81	19.07	183
3	Peanut meal.....	8.33	25.00	66.67	79	8	1.21	.27	22.31	24.81	90
4	{Peanut meal.....	8.33	25.00	66.67	77	8	1.18	.44	37.60	24.81	152
	{Velvet bean meal.....	5.00									
5	{Peanut meal.....	5.00	23.33	66.67	40	8	1.69	.45	20.63	19.07	108
	{Rice bran.....	5.00									
6	{Peanut meal.....	8.33	16.67	66.67	40	14	2.66	.60	22.56	21.69	104
	{Coconut meal.....	8.33									
7	{Peanut meal.....	7.50	15.00	70.00	100	8	1.68	.55	32.73	22.84	143
	{Ground oats.....	4.50									
	{Low-grade flour.....	3.00									
8	Rapeseed meal.....	5.00	28.33	66.67	39	14	2.38	.33	13.87	13.55	102
9	Rapeseed meal.....	8.33	25.00	66.67	39	14	2.56	.21	8.82	13.65	65
10	Coconut meal.....	5.00	28.33	66.67	40	14	2.58	.73	28.29	21.69	130
11	Coconut meal.....	8.33	25.00	66.67	104	14	2.39	.44	18.41	23.00	74
12	Coconut meal.....	13.33	20.00	66.67	64	14	1.92	.27	14.06	18.09	78
13	Coconut meal.....	16.67	16.67	66.67	40	14	2.43	.61	25.10	21.69	116
14	{Coconut meal.....	8.33	21.67	66.67	118	11	2.16	.57	26.39	21.39	123
	{Meat scrap.....	3.33									
15	Sesame-seed meal.....	8.33	25.00	66.67	122	11	2.07	.62	29.95	21.39	140
16	Rice bran.....	10.00	23.33	66.67	50	8	1.83	.35	19.13	23.66	81
17	Sesame-seed meal.....	9.09	18.18	72.73	1,169	10	.80	.32	40.00	.....	.....
18	{Sesame-seed meal.....	5.60	11.20	72.00	1,159	10	.88	.41	46.59	.....	.....
	{Ground wheat.....	11.20									
19	Soy-bean meal.....	10.00	20.00	70.00	2,310	10	1.05	.31	29.04	.....	.....
20	{Soy-bean meal.....	9.09	18.80	63.64	1,598	10	.96	.38	39.65	.....	.....
	{Wheat flour.....	9.09									
21	Wheat flour.....	14.00	14.00	72.00	1,130	10	1.21	.30	24.79	.....	.....
22	{Ground oats.....	15.00	20.00	60.00	72	14	.92	.28	30.43	.....	.....
	{Ground barley.....	5.00									
23	{Ground milo.....	20.00	5.00	60.00	72	14	.84	.36	42.86	.....	.....
	{Rice polish.....	15.00									
24	{Ground milo.....	20.00		60.00	72	14	.83	.29	34.94	.....	.....
	{Rice polish.....	15.00									
	{Ground beans.....	5.00									
25	{Ground milo.....	20.00		60.00	71	14	.94	.21	22.34	.....	.....
	{Rice bran.....	15.00									
	{Ground beans.....	5.00									
26	{Ground milo.....	20.00		55.00	72	14	.85	.37	43.53	.....	.....
	{Rice bran.....	5.00									
	{Boiled potatoes.....	20.00									

¹ Rations 1 to 16, inclusive, were fed to the usual "house run" of birds, other than Leghorns. Rations 17 to 26, inclusive, were fed to Leghorns only.

² Control taken as 100 per cent.

³ Average from two experiments.

TABLE 4.—Results of fleshing springs (battery experiments).

No.	Ration.			Number of birds.	Days fed.	Initial weight.			Gain.
	Special feeds.	Corn meal.	Butter-milk.			Lbs.	Lbs.	Per ct.	
1	Low-grade flour.....	Per ct. 5.25	Per ct. 17.5	Per ct. 65.00	390	14	3.45	0.72	20.87
	Middlings (standard wheat).....	5.25	-----	-----	391	14	3.35	.61	18.21
	Rolled oats.....	7.00	-----	-----	395	14	3.36	.61	18.15
					391	14	3.23	.56	17.34
2	Low-grade flour.....	5.00	16.67	66.67	596	14	2.61	.73	27.97
	Middlings (standard wheat).....	6.67	-----	-----	596	14	2.53	.62	24.51
	Oat flour.....	5.00	-----	-----	594	14	2.76	.65	23.55
					591	14	3.00	.68	22.66
					598	14	2.92	.53	18.15
					594	14	2.94	.55	18.71
					597	14	3.39	.60	17.70
3	Low-grade flour.....	4.50	15.00	70.00	645	14	2.66	.68	25.56
	Middlings (standard wheat).....	6.00	-----	-----	781	14	2.85	.49	17.19
	Ground oats.....	4.50	-----	-----	621	14	2.98	.72	24.16
					751	14	2.77	.53	19.13
					689	14	2.74	.53	19.34
					782	14	2.83	.63	22.26
4	Low-grade flour.....	1.67	20.00	66.67	787	14	3.11	.78	25.08
	Middlings (standard wheat).....	3.33	-----	-----	125	8	4.14	.92	22.22
	Oatmeal.....	8.33	-----	-----	391	8	3.65	.38	10.41
5	Low-grade flour.....	1.67	20.00	66.67					
	Middlings (standard wheat).....	3.33	-----	-----					
	Oatmeal.....	8.33	-----	-----	391	14	3.23	.56	17.34
6	Low-grade flour.....	3.00	15.00	70.00	381	14	2.58	.93	36.05
	Middlings (standard wheat).....	4.50	-----	-----	286	14	2.18	.95	43.58
	Peanut meal.....	7.50	-----	-----	574	14	2.52	.75	29.76
					573	14	2.64	.89	33.71

TABLE 5.—Results of fleshing hens (12-bird experiments).

Ration.					Gain.				Relative gain. ²	Feed per pound gain, experimental ration.
No.	Special feeds.	Corn meal.	Butter-milk.	Initial weight. ¹	Experimental ration.		Control ration.			
		Per ct.	Per ct.	Per ct.	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	Lbs.
1	Peanut meal.....	13.33	20.00	66.67	4.9	0.95	19.30	12.83	151	3.20
					5.1	-.19	-3.69	7.00	4	-----
					4.9	.41	8.32	10.34	80	6.30
2	Peanut meal..... Meat scrap.....	11.00 2.33	20.00	66.67	4.9	.48	16.61	12.83	129	3.61
					5.2	.66	12.65	7.00	182	4.16
					5.0	.33	6.68	10.34	64	7.74
3	Peanut meal..... Meat scrap..... Alfalfa meal.....	10.00 2.33 1.00	20.00	66.67	4.9	.74	15.11	12.83	118	3.76
					5.2	.51	9.77	7.00	140	4.54
					4.9	.25	5.13	10.34	50	9.51
4	Peanut meal..... Meat scrap..... Alfalfa meal.....	10.00 1.00 2.33	20.00	66.67	4.9	.49	9.98	12.83	78	5.64
					5.1	.19	3.68	7.00	53	12.96
					4.9	.43	8.81	10.34	85	4.65
5	Peanut meal..... Alfalfa meal.....	11.00 2.33	20.00	66.67	4.9	.55	11.15	12.83	87	5.50
					5.3	-.05	-.95	7.00	15	-----
					4.9	.34	6.96	10.34	67	7.53
6	Boiled potatoes.....	14.81	29.63	55.56	5.2	.83	16.04	10.36	155	5.44
					5.1	.49	9.70	13.94	70	10.40

¹ Average per bird.² Control taken as 100 per cent.

TABLE 6.—Results of fleshing hens (battery experiments).

No.	Ration.				Number of birds.	Days fed.	Initial weight.	Gain.			Relative gain. ¹
	Special feeds.		Corn meal.	Butter-milk.				Experimental ration.		Control ration.	
		Per ct.	Per ct.	Per ct.			Lbs.	Lbs.	Per ct.	Per ct.	Per ct.
1	Ground oats.....	10.00	30.00	60.00	39	14	5.01	1.76	15.17	13.17	115
2	Ground oats.....	10.00	30.00	60.00	76	10	4.58	.45	9.83	10.62	93
3	Ground oats.....	10.00	30.00	60.00	80	8	3.98	.33	8.29	7.66	108
4	{Ground oats.....	11.67	16.67	66.67	72	10	4.46	.65	14.57	10.62	137
	{Meat scrap.....	5.00									
5	{Ground oats.....	11.67	16.67	66.67	77	8	3.96	.31	7.83	7.66	102
	{Meat scrap.....	5.00									
6	{Ground oats.....	13.33	18.00	66.67	39	14	5.25	.42	8.00	13.17	61
	{Alfalfa meal.....	2.00									
7	{Ground oats.....	11.33	18.00	66.67	37	14	5.38	.52	9.67	13.17	73
	{Alfalfa meal.....	2.00									
8	{Ground oats.....	9.33	18.00	66.67	38	14	5.40	.44	8.15	13.17	62
	{Alfalfa meal.....	4.00									
	{Meat scrap.....	2.00									
9	{Ground oats.....	11.67	16.67	66.67	75	10	4.37	.35	6.01	10.62	57
	{Alfalfa meal.....	3.33									
	{Meat scrap.....	1.33									
	{Charcoal.....	.33									
10	{Ground oats.....	11.67	16.67	66.67	79	8	3.96	.28	7.07	7.66	92
	{Alfalfa meal.....	3.33									
	{Meat scrap.....	1.33									
	{Charcoal.....	.33									
11	Velvet-bean meal.....	4.00	29.33	66.67	{ 40	8	4.56	.33	7.24	6.22	116
					{ 40	8	4.40	.26	5.91	6.22	85
12	Soy-bean meal.....	8.33	25.00	66.67	40	8	4.84	.20	4.09	6.22	66
13	{Soy-bean meal.....	8.33	25.00		40	8	4.88	-.05	-1.02	6.22	
	{Water.....	66.67									
14	{Soy-bean meal.....	7.00	25.33	66.67	39	8	4.88	.19	3.90	6.22	63
	{Meat scrap.....	1.00									
15	{Meat scrap.....	1.67	25.00		40	8	4.89	.20	4.09	6.22	66
	{Water.....	66.67									
16	{Peanut meal.....	7.00	25.33	66.67	40	8	3.89	.30	7.71	6.22	124
	{Alfalfa meal.....	1.00									
17	{Low-grade flour.....	4.50	15.00	70.00	{ 501	11	3.25	.40	12.30		
	{ Middlings (standard wheat).....	3.00									
	{ Peanut flour.....	7.50									
18	{Low-grade flour.....	1.67	20.00	66.67	{ 495	14	3.14	.43	13.69		
	{ Middlings (standard wheat).....	3.33									
	{ Oat middlings.....	8.33									
19	{Low-grade flour.....	1.67	20.00	66.67	{ 316	8	3.56	.46	12.92		
	{ Middlings (standard wheat).....	3.33									
	{ Oat middlings.....	8.33									
20	{Low-grade flour.....	4.50	15.00	70.00	{ 318	8	3.70	.28	4.57		
	{ Middlings (standard wheat).....	6.00									
	{ Ground oats.....	4.50									

¹ Control taken as 100 per cent.

TABLE 7.—Gains made in 4, 8, 11, and 14 days by broilers fed the control ration.¹

Experiment No.	Number of birds.	Average initial weight.	Amount gained in—						
			4 days.		8 days.		11 days.		14 days.
			Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.
		Ounces.							
1	12	26.0	20.05	31.55	35.91	56.52	47.23	74.33	63.54
2	12	28.6	20.27	33.71	35.94	59.77	47.46	79.83	60.13
3	12	28.4	14.82	25.12	32.09	54.39	45.31	76.80	59.00
4	12	28.5	19.64	36.08	34.77	63.88	46.42	85.28	54.43
5	12	25.9	16.35	30.21	27.98	51.69	37.78	69.79	54.13
6	12	26.0	16.52	30.57	30.12	55.74	41.30	76.42	54.04
7	12	28.6	17.31	33.43	35.34	68.25	44.70	86.33	51.78
8	12	28.5	14.63	28.90	31.45	62.12	49.50	78.02	50.63
Total.....	96								
Average.....			17.45	31.18	32.95	58.88	43.81	78.29	55.96
9	12	26.0	16.82	33.98	30.58	61.78	38.63	78.04	49.50
10	12	26.0	14.69	29.95	29.64	60.43	38.95	79.41	49.05
11	12	38.8	16.78	34.67	32.51	67.17	41.71	86.18	48.40
12	12	25.5	7.30	15.30	19.69	41.26	36.09	75.63	47.72
13	12	25.6	8.61	18.48	22.41	48.09	37.24	79.91	46.60
14	12	38.7	21.15	45.64	32.35	69.81	39.83	77.32	46.34
15	12	25.7	6.16	14.13	20.35	46.70	35.84	82.24	43.58
16	12	38.8	18.44	43.98	27.72	66.11	36.25	86.45	41.93
17	12	35.1	10.79	25.84	20.61	49.35	27.13	64.97	41.76
18	12	31.7	15.09	37.07	23.48	57.68	31.91	78.38	40.71
19	12	38.9	14.59	36.19	29.13	72.26	37.01	91.81	40.31
20	12	24.8	17.46	43.45	26.51	65.98	37.10	92.33	40.18
Total.....	144								
Average.....			13.99	31.32	26.25	58.76	36.47	81.64	44.67
21	12	30.9	10.04	25.13	22.36	55.96	30.45	76.20	39.96
22	12	34.7	11.77	29.57	23.48	58.99	31.72	79.70	39.80
23	12	36.4	9.06	24.83	17.80	47.78	25.15	68.92	36.49
24	12	35.8	10.49	28.76	22.14	60.70	26.54	72.77	36.47
25	12	30.9	9.94	27.29	19.54	53.65	26.15	71.80	36.42
26	12	30.8	11.00	30.47	21.24	58.84	28.90	80.06	36.10
27	12	24.8	6.33	17.86	11.12	31.37	26.04	73.48	35.44
28	12	30.9	8.82	25.95	16.58	48.78	24.29	71.46	33.99
29	12	31.7	10.58	31.78	18.77	56.38	24.41	73.33	33.29
30	12	22.6	12.56	38.08	19.04	57.63	25.93	78.48	33.04
31	12	28.6	11.83	36.78	18.24	56.70	24.35	75.69	32.17
32	12	31.0	8.20	25.55	19.10	59.52	26.68	83.14	32.09
33	12	36.4	8.11	25.38	15.62	48.89	22.57	73.77	31.95
34	12	24.8	12.20	38.70	20.08	63.71	28.38	90.04	31.52
35	12	31.1	8.82	28.73	18.75	61.07	20.50	66.78	30.70
Total.....	180								
Average.....			9.98	28.82	18.92	54.63	26.20	76.81	34.63
36	12	26.0	7.05	23.86	13.34	45.14	21.24	71.88	29.55
37	12	28.5	11.72	40.39	13.19	45.45	20.75	71.50	29.02
38	12	31.1	6.92	24.40	15.21	53.63	23.18	81.73	28.36
39	12	36.8	6.01	21.32	16.19	57.45	21.71	77.04	28.18
40	12	31.7	5.97	21.45	12.56	45.13	20.29	72.91	27.83
41	12	30.9	8.85	31.86	17.46	62.85	20.41	73.47	27.78
42	12	25.9	11.11	40.02	21.51	77.49	23.42	84.37	27.76
43	12	38.8	5.27	20.90	12.10	47.98	16.53	65.44	25.22
44	12	36.4	4.76	19.09	11.70	46.91	16.39	65.72	24.94
45	12	31.0	7.09	28.45	15.23	61.12	21.14	84.83	24.92
46	12	31.3	11.35	46.90	15.84	65.45	19.01	78.55	24.20
47	12	26.2	9.52	41.11	12.99	56.09	17.14	74.01	23.16
48	12	24.8	2.19	9.69	10.41	46.06	18.22	80.62	22.60
49	12	38.0	5.10	23.85	9.93	46.85	15.24	71.28	21.38
50	12	38.1	4.00	18.19	9.73	46.00	13.15	62.17	21.15
51	12	38.7	4.21	20.81	8.88	43.90	14.12	69.80	20.23
Total.....	192								
Average.....			6.95	27.37	13.52	53.25	18.87	74.32	25.39
Grand total.....	612								
Grand average.....			12.09	30.10	22.91	57.05	31.34	78.04	40.16

¹Corn meal (40 parts) + butter milk (60 parts).

TABLE 8.—Gains made in 4, 8, 11, and 14 days by springs fed the control ration.¹

Experiment No.	Num-ber of birds.	Aver-age initial weight.	Amount gained in—						
			4 days.		8 days.		11 days.		14 days.
			Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.
		Ounces.							
1.....	12	54.7	16.22	57.01	30.16	68.81	36.28	82.77	43.83
2.....	12	43.9	12.73	31.47	27.38	67.69	34.53	85.36	40.45
3.....	12	54.7	13.97	36.30	21.26	55.25	30.62	79.57	38.48
4.....	12	43.8	12.65	33.83	27.38	73.23	33.74	90.24	37.39
5.....	12	44.0	11.13	30.99	24.07	67.01	31.72	88.31	35.92
6.....	12	55.0	14.04	40.86	25.91	75.41	28.88	84.05	34.36
7.....	48	54.8	15.85	46.41	23.78	69.63	29.88	87.50	34.15
8.....	12	45.6	8.83	33.15	18.70	70.20	22.37	83.97	26.44
9.....	48	57.1	11.70	43.49	16.95	63.01	25.15	93.49	26.90
10.....	48	58.2	10.92	44.19	13.22	53.50	23.55	95.35	24.71
11.....	48	55.5	2.40	9.96	13.86	57.51	18.67	77.47	24.10
12.....	48	56.8	5.88	33.31	10.00	56.66	14.71	83.34	17.65
13.....	24	41.9	.....	.....	14.04	51.58	21.51	79.49	27.06
14.....	48	42.3	.....	.....	13.99	42.42	24.64	74.71	32.98
Total.....	396	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	.....	.....	.....	17.28	59.81	24.43	84.56	28.88

¹ Corn meal (40 parts) + buttermilk (60 parts).TABLE 9.—Gains made in 4, 8, 11, and 14 days by roasters fed the control ration.¹

Experiment No.	Num-ber of birds.	Aver-age initial weight.	Amount gained in—						
			4 days.		8 days.		11 days.		14 days.
			Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.
		Ounces.							
1.....	12	66.1	15.50	39.95	28.04	72.27	33.55	86.47	38.80
2.....	12	66.1	15.87	45.36	28.54	81.57	31.65	90.45	34.99
3.....	12	66.0	12.49	38.62	25.11	77.64	27.68	85.59	32.34
4.....	12	74.2	14.00	44.05	22.08	69.48	27.24	85.71	31.78
5.....	12	77.4	19.18	61.57	22.49	72.20	27.22	87.38	31.15
6.....	12	74.4	14.10	50.98	20.55	74.30	24.60	88.94	27.66
7.....	12	74.3	12.50	47.28	18.31	69.25	22.74	86.01	26.44
8.....	12	64.9	12.13	45.48	19.81	74.28	23.09	86.58	26.67
9.....	12	82.6	9.65	37.58	19.59	76.29	23.04	89.72	25.68
10.....	12	82.6	10.82	43.95	17.99	73.07	22.55	91.59	24.62
11.....	12	82.8	9.62	39.69	17.45	71.99	21.66	89.36	24.24
12.....	12	73.0	10.57	43.99	17.15	71.37	21.71	90.35	24.03
13.....	12	76.2	10.90	45.48	14.77	62.99	20.21	86.18	23.45
14.....	12	65.8	10.70	49.45	18.00	83.17	19.39	89.60	21.64
15.....	12	67.1	10.88	46.48	16.64	71.08	19.47	83.17	23.41
16.....	12	66.3	11.24	55.13	16.08	73.39	19.25	87.86	21.91
17.....	12	62.8	11.66	37.71	17.93	84.96	17.97	84.96	21.15
18.....	12	70.2	7.46	39.70	11.95	63.60	15.20	80.89	18.79
19.....	24	87.1	12.27	68.97	14.72	82.74	18.40	103.43	17.79
20.....	12	79.5	10.47	59.05	15.51	87.48	16.81	94.81	17.73
21.....	12	75.6	4.24	26.14	10.35	63.81	12.97	79.96	16.22
22.....	24	82.6	6.47	38.44	8.09	48.07	12.30	73.08	16.83
23.....	12	75.5	6.97	42.14	11.46	69.29	13.78	83.31	16.54
24.....	12	76.4	5.94	37.78	10.04	63.75	12.43	78.92	15.75
25.....	12	65.1	11.07	69.23	16.06	100.44	17.89	111.88	15.99
26.....	12	80.8	4.62	54.38	5.17	66.45	4.91	63.11	7.78
Total.....	336								
Average.....			11.11	49.71	17.29	77.36	20.68	92.53	22.35

¹ Corn meal (40 parts) + buttermilk (60 parts).

TABLE 10.—Gains made in 4, 8, 11, and 14 days by hens fed the control ration.¹

Experiment No.	Num-ber of birds.	Aver-age initial weight.	Amount gained in—						
			4 days.		8 days.		11 days.		14 days.
			Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.	Per-centage of total gain.	Per-centage of initial weight.
		Ounces.							
1.....	12	66.8	10.22	47.45	15.84	73.54	19.87	92.25	21.54
2.....	12	77.2	9.26	35.18	15.55	58.89	21.59	82.03	26.32
3.....	12	70.8	7.88	39.48	13.51	67.69	16.64	83.37	19.96
4.....	12	78.6	6.91	35.80	11.20	68.03	15.55	80.57	19.30
5.....	12	72.1	4.54	24.25	10.67	56.98	12.50	66.77	18.72
6.....	12	79.1	12.85	72.27	16.84	94.71	15.13	85.10	17.78
7.....	12	79.5	3.62	22.57	9.47	59.04	12.68	79.05	16.04
8.....	12	66.5	3.51	22.30	8.52	54.13	13.39	85.07	15.74
9.....	12	70.3	1.01	64.17	9.87	62.71	14.98	95.17	15.74
10.....	12	69.6	6.24	40.00	12.94	82.95	11.16	71.54	15.60
11.....	12	78.7	4.23	27.99	8.46	55.99	12.76	84.45	15.11
12.....	12	78.7	5.55	33.41	8.94	53.83	12.86	77.06	16.61
13.....	12	81.6	9.70	69.58	12.68	90.96	12.46	89.38	13.94
14.....	12	70.2	3.30	25.98	10.18	80.16	8.55	67.32	12.70
15.....	12	83.6	3.15	24.90	7.92	62.61	11.49	90.83	12.65
16.....	12	78.6	4.19	32.66	7.39	57.60	12.15	94.70	12.83
17.....	12	66.3	1.63	13.59	4.54	37.92	8.12	67.69	12.00
18.....	12	78.7	5.18	46.46	7.34	65.83	10.17	91.21	11.15
19.....	12	84.6	3.24	29.67	6.13	56.14	5.93	54.30	10.92
20.....	12	69.8	6.09	57.13	6.93	65.01	8.76	82.18	10.66
21.....	12	79.5	—1.32	—	2.51	24.23	6.77	65.35	10.36
22.....	12	84.6	—1.02	—	4.13	40.25	6.43	62.67	10.26
23.....	12	78.7	3.34	32.30	6.93	67.02	10.84	104.84	10.34
24.....	12	78.4	6.05	60.62	9.85	98.70	12.62	126.45	9.98
25.....	12	82.5	1.61	16.48	5.16	52.81	7.66	78.40	9.77
26.....	12	81.5	8.76	90.31	11.34	116.91	10.33	106.49	9.70
27.....	12	93.5	6.18	69.44	8.34	93.71	7.21	81.01	8.90
28.....	12	78.9	2.62	31.49	2.87	34.50	8.55	102.76	8.32
29.....	12	81.8	1.66	23.71	4.27	61.00	5.17	73.85	7.00
30.....	12	78.6	1.66	23.85	4.07	58.48	7.82	112.36	6.96
31.....	12	85.4	1.81	26.62	6.68	98.24	5.98	87.94	6.80
32.....	12	85.0	3.15	48.46	7.50	115.38	5.19	79.85	6.50
33.....	12	79.2	6.78	—	3.10	46.83	8.22	124.17	6.62
34.....	12	92.9	1.24	19.77	3.99	63.62	3.30	36.37	6.26
35.....	12	78.9	2.62	31.49	2.87	34.50	8.55	102.76	8.32
36.....	12	78.7	1.44	28.07	.55	10.72	3.52	68.62	5.13
37.....	12	82.18	1.09	30.03	2.77	76.31	3.16	87.05	3.63
38.....	12	85.4	.98	53.85	2.75	151.10	7.58	86.81	1.82
Total.....	456								
Average.....			4.08	34.31	7.75	65.18	9.99	84.02	11.89

¹ Corn meal (40 parts)+buttermilk (60 parts).

TABLE 11.—*Weight lost in dressing poultry before feeding.*

BROILERS.

Experiment No.	Number of birds.	Average weight of birds.			Percentage of final weight lost as—				Cooler loss as percentage of dressed weight.
		Final live.	Dressed.	Chilled.	Blood.	Feathers.	Cooler loss.	Total.	
		Ounces.	Ounces.	Ounces.					
1.....	6	26.3	23.4	23.2	3.97	7.16	0.76	11.89	0.85
2.....	6	29.1	26.1	25.8	3.73	6.76	1.00	11.49	1.11
3.....	6	25.2	22.5	22.3	4.27	6.33	.71	11.31	.78
4.....	6	31.7	28.5	28.2	4.23	5.99	.79	11.01	.89
5.....	6	35.4	31.8	31.6	3.61	6.43	.51	10.55	.57
6.....	6	28.7	25.8	25.6	4.24	5.68	.80	10.72	.89
7.....	6	44.1	38.5	38.2	4.82	7.89	.83	13.54	.95
8.....	6	38.0	33.4	33.2	4.32	7.75	.60	12.67	.69
9.....	6	26.1	23.6	23.6	3.90	5.92		9.75	
10.....	12	30.8	27.8	27.3	3.76	5.72	1.65	11.13	1.83
11.....	12	30.5	27.2	27.0	3.60	7.25	.57	11.42	.65
12.....	6	37.5	34.0	33.9	3.76	5.41	.40	9.57	.43
13.....	12	30.7	27.5	27.4	4.11	6.56	.28	10.95	.31
14.....	12	29.6	26.4	26.0	4.08	6.66	.43	12.17	.49
15.....	6	40.7	36.1	35.7	4.83	6.57	1.08	12.48	1.22
16.....	6	33.9	30.1	29.8	3.39	7.90	.69	11.98	.78
17.....	6	30.5	26.8	26.7	4.15	7.91	.28	12.34	.33
Total.....	126								
Average.....		30.8	28.5	28.3	4.02	6.67	.68	11.37	.76

SPRINGS.

1.....	6	54.8	47.7	47.5	4.70	8.23	0.43	13.36	0.51
2.....	6	66.0	58.5	57.8	4.06	7.40	1.04	12.50	1.18
Total.....	12								
Average.....		60.4	53.1	52.6	4.38	7.81	.74	12.93	.85

ROASTERS.

1.....	6	82.7	72.2	72.0	4.05	8.65	0.19	12.89	0.22
2.....	6	74.3	65.2	64.9	4.05	8.20	.37	12.62	.42
3.....	6	67.2	59.2	58.9	3.46	8.40	.52	12.38	.60
Total.....	18								
Average.....		74.7	65.5	65.4	3.85	8.42	.36	12.63	.41

HENS.

1.....	6	73.8	67.5	67.2	3.28	5.23	0.36	8.87	0.39
2.....	6	92.3	85.2	85.0	2.37	5.55	.18	7.88	.20
3.....	6	74.0	68.0	67.7	3.61	4.56	.33	8.50	.35
4.....	6	82.1	74.9	74.7	2.80	5.98	.24	9.02	.27
5.....	6	81.0	73.6	72.7	3.55	5.63	.25	9.43	.27
6.....	6	74.3	67.8	67.5	3.78	4.92	.41	9.11	.45
7.....	6	85.3	77.4	77.2	3.88	5.37	.25	9.50	.27
8.....	6	69.0	62.9	62.5	3.54	5.37	.44	9.35	.48
Total.....	48								
Average.....		79.0	72.1	71.8	3.35	5.33	.31	8.99	.34

TABLE 12.—*Weight lost in dressing poultry fed the control ration.*¹

BROILERS.

Experiment No.	Number of birds.	Average weight of birds.			Percentage of final live weight lost as—				Cooler loss as percentage of dressed weight.
		Final live.	Dressed.	Chilled.	Blood.	Feathers.	Cooler loss.	Total.	
		Ounces.	Ounces.	Ounces.					
1.....	12	33.7	30.5	30.2	3.96	5.66	1.00	10.62	1.11
2.....	12	37.8	34.1	33.8	4.30	5.66	.74	10.70	.82
3.....	12	45.7	41.1	40.7	3.77	6.35	.97	11.09	1.08
4.....	6	60.2	53.7	53.4	4.07	6.72	.45	11.24	.50
5.....	6	55.1	49.0	48.7	4.07	7.00	.43	11.50	.48
6.....	12	38.4	35.1	34.6	3.74	4.89	1.28	9.91	1.40
7.....	12	38.6	35.0	34.5	3.23	6.36	1.36	10.95	1.50
8.....	12	34.0	33.4	33.4	4.60	5.36	.18	10.14	.19
9.....	12	47.0	42.3	41.8	3.91	6.16	1.03	11.10	1.15
10.....	12	41.8	37.3	37.0	4.02	6.75	.70	11.47	.79
11.....	12	34.8	30.9	30.4	4.18	7.22	1.14	12.54	1.29
12.....	4	41.9	37.8	37.5	4.11	5.68	.63	10.42	.70
13.....	4	49.8	44.4	44.0	5.23	5.58	.79	11.60	.89
14.....	4	36.2	32.4	32.1	3.53	6.94	.86	11.33	.95
Total.....	132								
Average.....		41.1	37.2	36.8	4.01	6.45	.87	11.33	.97

SPRINGS.

1.....	12	73.8	64.9	64.5	4.06	8.06	0.52	12.64	0.59
2.....	12	89.3	78.6	78.2	4.48	7.49	.41	12.38	.48
Total.....	24								
Average.....		81.5	71.7	71.4	4.27	7.78	.47	12.52	.54

ROASTERS.

1.....	12	102.9	91.0	90.5	4.05	7.50	0.44	11.99	0.51
2.....	12	94.9	85.6	84.9	4.16	5.67	.74	10.57	.81
3.....	4	77.8	68.4	68.1	4.25	7.77	.39	12.41	.45
Total.....	28								
Average.....		95.9	85.5	84.9	4.13	6.75	.56	11.44	.63

HENS.

1.....	11	85.2	78.8	78.4	3.20	4.31	0.42	7.92	0.45
2.....	12	101.5	93.6	93.1	3.26	4.54	.45	8.25	.48
3.....	12	69.8	63.8	63.7	3.28	5.20	.21	8.69	.23
4.....	11	87.1	79.2	79.0	3.46	5.68	.20	9.34	.21
5.....	12	92.4	85.3	85.1	3.02	4.70	.21	7.93	.22
6.....	12	82.6	76.4	76.2	3.56	4.02	.21	7.79	.23
7.....	12	87.2	80.0	79.4	2.96	5.29	.63	8.88	.70
8.....	12	77.2	70.6	70.5	3.40	5.07	.40	8.87	.44
Total.....	95								
Average.....		85.4	78.4	78.2	3.27	4.85	.34	8.46	.37

¹ Corn meal (40 parts) + buttermilk (60 parts).

TABLE 13.—*Distribution of weight of poultry before feeding.*

BROILERS.

Experiment No.	Number of birds.	Total.	Chilled weight.								
			Meat.	Skin.	Gizzard fat.	Edible organs.	Eggs.	Total edible.	Offal.	Bones.	Total inedible.
1.....	6	Ozs.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
2.....	6	23.2	38.98	7.38	1.26	6.83	.....	54.45	27.76	17.79	43.55
3.....	6	25.8	43.66	7.42	1.20	6.54	.....	58.82	24.36	16.82	41.18
4.....	6	22.3	40.11	7.75	.90	7.80	.....	56.56	26.77	16.66	43.44
5.....	6	28.2	41.55	8.23	2.08	6.56	.....	58.42	25.40	16.17	41.58
6.....	6	31.6	43.73	6.96	.79	6.17	.....	57.65	24.68	17.67	42.35
7.....	6	25.6	39.19	8.27	1.10	6.86	.....	55.42	25.92	18.66	44.58
8.....	6	38.2	41.68	7.77	.99	6.85	.....	56.30	25.21	17.50	43.70
9.....	6	33.2	42.94	6.99	.58	7.50	.....	57.43	25.02	16.96	42.57
10.....	6	23.6	38.01	7.96	1.55	7.47	.....	54.99	29.02	15.98	45.01
11.....	6	27.4	40.94	6.82	1.11	7.37	.....	56.21	27.01	16.78	43.79
12.....	6	27.7	40.98	6.87	.91	6.53	.....	55.34	26.36	18.30	44.66
13.....	6	33.9	40.50	7.63	1.75	6.56	.....	56.44	25.89	17.67	43.56
14.....	6	26.0	43.63	7.02	1.00	6.84	.....	58.49	25.67	15.83	41.51
15.....	6	24.2	36.24	6.65	.74	7.21	.....	50.84	26.96	22.21	42.16
16.....	6	35.7	35.84	8.21	2.68	6.52	.....	53.24	32.71	14.04	46.76
17.....	6	44.0	40.43	7.20	.78	6.07	.....	54.48	22.11	23.39	45.52
18.....	6	21.7	38.63	6.94	1.39	6.55	.....	53.51	27.12	19.37	46.49
19.....	6	29.8	41.46	10.13	2.95	5.62	.....	60.16	22.06	17.78	39.84
20.....	6	26.7	38.95	7.05	1.10	7.76	.....	54.86	27.55	17.59	45.14
Total.....	114	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	28.9	40.39	7.54	1.31	6.82	.....	56.06	26.19	17.75	43.94

SPRINGS.

1.....	6	47.5	46.43	7.89	6.46	0.80	.....	61.58	22.15	16.28	38.43
2.....	6	57.8	45.40	9.73	5.43	3.06	.....	63.62	21.15	15.24	36.39
Total.....	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	52.6	45.92	8.81	5.95	1.93	.....	62.61	21.65	15.76	37.41

ROASTERS.

1.....	6	72.0	44.48	11.07	5.02	4.44	.....	65.01	19.41	15.55	34.99
2.....	6	64.9	43.36	10.26	5.89	3.89	.....	63.40	21.48	15.11	36.60
3.....	6	53.9	44.32	7.12	6.13	.68	.....	58.25	23.98	17.78	41.75
Total.....	18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	62.3	44.05	9.48	5.68	3.00	.....	62.21	21.62	16.15	37.77

HENS.

1.....	6	67.2	40.19	13.67	9.62	4.81	1.95	70.24	18.75	11.02	29.77
2.....	6	85.0	39.05	13.35	11.71	4.94	2.57	71.62	18.25	10.20	28.45
3.....	6	67.7	36.77	15.79	12.08	4.26	4.25	73.15	16.66	10.19	26.85
4.....	6	74.7	37.80	14.98	8.23	4.89	3.45	69.35	18.94	11.72	30.64
5.....	6	72.7	39.16	14.71	10.37	4.55	1.63	70.42	18.52	11.05	29.57
6.....	6	67.5	39.31	13.33	7.94	5.64	1.76	67.98	20.45	11.57	32.02
7.....	6	77.2	38.55	15.62	10.88	4.57	2.05	71.67	17.03	11.23	28.31
8.....	6	62.5	40.09	16.01	8.09	4.74	1.36	70.29	17.92	11.78	29.70
Total.....	48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	70.1	38.87	14.68	9.87	4.80	2.38	70.59	18.32	11.10	29.42

TABLE 14.—*Distribution of weight of poultry fed the control ration.¹*

BROILERS.

Experiment No.	Number of birds.	Total.	Chilled weight.								
			Meat.	Skin.	Gizzard fat.	Edible organs.	Eggs.	Total edible.	Offal.	Bones.	Total inedible.
		<i>Ozs.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
1.....	4	30.2	43.02	7.63	4.57	5.81	.....	61.03	23.46	15.51	38.97
2.....	4	33.8	42.15	7.26	2.40	6.54	.....	58.35	25.29	16.35	41.64
3.....	4	40.7	38.60	14.01	5.92	6.38	.....	64.91	21.12	13.97	45.09
4.....	4	34.6	37.98	11.40	5.38	6.41	.....	61.17	23.38	15.44	38.82
5.....	4	34.1	36.36	11.30	4.84	6.46	.....	58.97	24.67	16.36	41.03
6.....	4	37.0	40.97	8.07	2.98	7.28	.....	59.30	24.83	16.87	40.70
7.....	4	41.3	38.47	10.98	4.54	6.53	.....	60.52	22.98	16.50	39.48
8.....	4	41.8	39.05	12.59	4.68	7.13	.....	63.44	21.91	14.65	36.56
9.....	4	28.5	39.57	8.84	3.40	6.83	.....	58.64	24.63	16.71	41.34
10.....	4	36.3	36.36	10.81	5.01	6.97	.....	59.15	24.43	16.42	40.85
11.....	4	37.5	36.48	12.52	3.61	5.84	.....	58.45	24.09	17.46	41.55
12.....	4	25.7	39.64	8.91	3.65	6.63	.....	58.83	23.64	17.54	41.18
13.....	4	44.1	39.51	9.51	3.90	6.12	.....	59.04	24.90	16.06	40.96
14.....	4	32.1	37.90	11.93	4.11	6.52	.....	60.46	24.00	15.54	39.54
Total.....	56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	35.6	39.00	10.41	4.21	6.53	.....	60.15	23.81	16.10	39.91

SPRINGS.

1.....	4	64.5	43.28	13.22	5.57	3.91	.....	65.98	20.77	13.25	34.02
2.....	4	78.2	42.91	13.07	5.49	6.67	.....	68.14	19.14	12.71	31.86
Total.....	8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	71.4	43.10	13.15	5.53	5.29	.....	67.07	19.96	12.98	32.94

ROASTERS.

1.....	4	84.9	40.35	13.60	7.60	5.18	.....	66.73	18.41	14.85	33.26
2.....	4	68.1	40.85	11.61	3.95	5.69	.....	62.10	22.55	15.35	37.90
Total.....	8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	76.5	40.60	12.61	5.81	5.44	.....	64.46	20.48	15.10	35.58

HENS.

1.....	4	78.4	37.96	14.14	12.37	6.09	2.06	72.62	18.05	9.32	27.37
2.....	4	93.1	36.23	14.40	11.92	4.56	3.40	70.51	18.36	11.12	29.48
3.....	4	63.7	38.65	16.22	9.97	5.30	1.35	71.49	18.76	9.73	28.49
4.....	4	79.0	38.41	16.51	8.93	6.42	1.57	71.84	18.23	9.87	28.16
5.....	4	85.1	37.73	13.92	10.73	4.68	4.25	71.31	18.04	10.70	28.74
6.....	4	76.2	36.59	15.35	11.03	4.40	4.11	71.48	17.49	11.04	28.53
7.....	4	79.4	39.13	13.58	9.57	4.63	3.68	70.59	19.02	10.37	29.39
8.....	4	70.3	38.75	13.22	9.50	5.60	4.27	71.34	19.39	9.26	28.65
Total.....	32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	.....	78.2	37.93	14.67	10.50	5.21	3.09	71.40	18.43	10.18	28.61

¹ Corn meal (40 parts) + buttermilk (60 parts).

TABLE 15.—*Composition of poultry before feeding.*

BROILERS.

Experiment No.	Number of birds.	Meat.			Skin.			Edible viscera.			Crude gizzard fat.	
		Water.	Fat.	Protein.	Water.	Fat.	Protein.	Water.	Fat.	Protein.	Water.	Fat.
1.....	6	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
2.....	6	75.41	3.02	19.88	58.15	23.98	16.88	72.43	2.26	20.19	32.00	60.74
3.....	6	75.70	2.37	20.38	59.07	22.12	17.63	73.96	2.52	19.88	27.53	65.61
4.....	6	75.57	1.79	20.63	61.26	17.49	19.88	74.73	2.01	20.75	41.57	47.16
5.....	6	75.16	3.78	20.06	53.43	28.78	16.75	74.00	3.25	18.50	29.87	60.99
6.....	6	75.00	3.03	21.00	54.88	25.25	18.25	73.73	2.82	18.56	20.47	72.81
7.....	6	74.63	3.61	21.19	57.96	24.86	16.88	75.46	2.68	20.63	29.26	64.08
8.....	6	74.46	3.42	21.63	56.40	25.33	17.44	75.21	2.55	21.00	35.77	54.57
9.....	6	75.64	2.17	21.19	60.93	17.42	20.50	75.22	2.11	20.88	37.80	51.14
10.....	6	74.89	2.58	21.94	57.45	22.72	19.19	73.83	3.53	20.56	36.84	50.49
11.....	6	72.97	3.53	22.63	43.76	41.69	14.25	74.64	2.35	19.75	11.31	87.03
11.....	6	74.82	3.91	21.31	56.87	25.00	18.00	75.12	4.00	19.19	40.16	45.86
Total.....	66											
Average..		74.93	3.02	21.08	56.33	24.97	17.79	74.39	2.73	19.99	31.14	60.04

SPRINGS.

1.....	6	73.52	2.30	22.38	55.06	24.54	19.31	74.33	1.69	20.09	29.40	61.41
2.....	6	72.73	3.66	21.69	44.96	38.61	15.13	73.92	2.23	20.75	11.12	85.17
Total.....	12											
Average..		73.13	2.98	22.04	50.01	31.58	17.22	74.13	1.96	20.42	20.26	73.29

ROASTERS.

1.....	6	72.38	3.98	21.94	40.48	45.79	13.51	73.84	2.72	20.84	9.80	87.94
2.....	6	72.25	4.71	21.60	43.79	41.04	14.24	73.30	3.20	20.55	14.14	83.00
3.....	6	75.01	2.07	21.69	61.57	18.24	20.06	75.32	2.06	20.06	44.94	42.00
Total.....	18											
Average..		73.21	3.59	21.76	48.61	35.02	15.94	74.15	2.66	20.48	22.96	70.98

HENS.

1.....	6	70.54	7.30	20.94	27.90	62.54	8.69	72.76	6.08	19.56	8.99	89.17
2.....	6	69.23	8.33	20.88	25.77	63.73	9.38	69.10	9.19	18.13	8.43	89.54
3.....	6	68.94	8.14	21.31	24.66	66.97	6.88	72.34	5.12	19.81	8.92	88.94
4.....	6	70.30	6.76	22.00	27.16	62.20	10.63	70.58	6.44	20.38	8.56	89.15
5.....	6	70.03	6.68	21.25	27.69	62.23	10.19	71.51	5.26	20.25	10.52	86.58
6.....	6	71.10	5.18	21.88	34.35	53.97	11.44	69.70	8.03	18.69	12.76	81.51
7.....	6	70.22	7.41	21.31	29.84	60.42	9.50	70.40	7.61	18.63	12.28	84.56
8.....	6	72.36	5.38	21.75	32.23	58.58	10.63	72.04	6.29	19.00	11.39	88.88
Total.....	48											
Average..		70.34	6.90	21.41	28.70	61.33	9.67	70.99	6.75	19.31	10.23	87.29

TABLE 16.—Composition of poultry fed the control ration.¹

BROILERS.

Experiment No.	Number of birds.	Meat.			Skin.			Edible viscera.			Gizzard fat.		
		Water.	Fat.	Protein.	Water.	Fat.	Protein.	Water.	Fat.	Protein.	Water.	Fat.	Protein.
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
1.....	4	71.79	6.76	19.56	33.20	56.69	9.44	69.48	5.75	19.00	11.48	86.25	2.27
2.....	4	72.83	6.16	19.00	35.46	47.63	12.75	73.98	3.61	18.00	11.37	87.98	2.25
3.....	4	73.42	5.73	20.38	41.02	45.98	12.13	75.04	2.66	18.75	14.00	83.32	3.38
4.....	4	72.72	6.57	17.25	44.83	40.42	13.31	74.82	3.01	18.63	23.68	69.39	5.13
5.....	4	73.66	5.00	19.13	39.50	47.78	12.50	74.60	3.36	19.81	13.00	81.69	2.56
6.....	4	73.56	4.56	21.55	38.66	49.40	11.81	74.81	3.31	19.69	18.87	78.43	4.13
7.....	4	71.97	7.73	20.75	48.10	36.12	14.69	74.84	3.44	20.13	16.61	78.87	3.97
8.....	4	71.02	8.04	20.13	43.25	43.59	13.00	73.85	4.78	18.44	15.48	81.11	3.19
9.....	4	73.61	4.90	20.69	39.87	47.38	11.25	75.35	3.09	20.50	14.52	82.26	3.75
10.....	4	70.62	8.95	20.06	41.68	45.17	12.81	75.65	3.29	19.44	13.57	83.02	3.31
11.....	4	74.30	4.61	20.63	48.31	37.70	13.56	75.21	3.68	19.44	15.15	81.88	3.06
12.....	4	73.87	4.75	20.56	37.66	51.64	11.94	75.17	3.00	19.56	13.88	85.60	3.25
Total.....	48												
Average.....		72.78	6.15	19.97	40.96	45.80	12.43	74.40	3.58	19.28	15.14	81.65	3.35

SPRINGS.

1.....	4	73.20	4.69	20.54	38.41	49.53	11.69	73.81	3.30	18.18	13.67	83.49	.....
2.....	4	72.94	4.73	20.87	36.94	51.70	10.46	73.55	3.70	19.11	11.23	86.28	.....
Total.....	8												.....
Average.....		73.07	4.71	20.76	37.68	50.67	11.08	73.68	3.50	18.65	12.45	84.89	.....

ROASTERS.

1.....	4	71.89	6.11	20.94	38.22	49.86	11.75	73.88	3.31	20.25	10.34	88.03	.....
2.....	4	72.38	5.86	19.50	42.67	43.49	12.56	73.73	4.24	18.94	14.68	81.87	.....
Total.....	8												.....
Average.....		72.14	5.99	20.22	40.45	46.68	12.16	73.81	3.78	19.60	12.51	84.95	.....

HENS.

1.....	4	69.29	8.21	21.75	27.95	63.11	8.81	64.39	15.55	16.94	9.32	88.85	.....
2.....	4	70.02	7.35	21.38	26.89	63.72	9.31	70.92	10.02	18.44	19.39	77.98	.....
3.....	4	71.52	7.06	19.50	30.48	60.48	10.69	66.58	12.21	17.69	12.93	85.83	.....
4.....	4	70.65	7.56	20.38	30.26	60.41	9.19	66.98	11.65	16.06	12.44	84.81	.....
5.....	4	71.50	6.17	21.00	28.90	63.09	9.81	65.30	15.09	16.38	10.73	86.88	.....
6.....	4	68.49	8.24	22.38	25.54	65.60	9.25	68.46	8.69	19.25	8.10	87.77	.....
7.....	4	70.38	6.90	21.38	27.95	61.19	11.31	67.41	11.79	17.56	8.35	80.47	.....
8.....	4	69.92	7.09	21.31	30.35	60.12	10.19	65.00	14.90	17.13	8.39	91.31	.....
Total.....	32												.....
Average.....		70.22	7.32	21.14	28.54	62.22	9.82	66.88	12.50	17.43	11.21	85.50	.....

¹ Corn meal (40 parts)+buttermilk (60 parts).

DISCUSSION OF RESULTS.

EFFECTS OF RATIONS ON DIFFERENT CLASSES OF BIRDS.

Broilers fed the rations containing a protein concentrate, such as peanut meal, coconut meal, soy-bean meal, or meat scrap (Table 2), made appreciably better gains than those given the control ration of corn meal and buttermilk. In the majority of cases the other rations proved of less value than the control ration. As they grow rapidly,

broilers require feeds containing tissue-forming substances. For this reason the rations containing the protein concentrates undoubtedly proved valuable, a conclusion supported also by the data in Table 3. Experiments 17 to 26 in Table 3 were conducted on Leghorn broilers, using the "house run" of birds in a commercial feeding plant in San Francisco, Calif. Each lot comprised more than a thousand birds. Rations 17 to 20 produced very good results, particularly those containing sesame-seed meal and soy-bean meal. Here again the value of protein concentrates in rations for broilers is evident.

With the exception of No. 6, all the rations fed the "springs" (Table 4) were made up, for the most part, of corn, low-grade flour, standard wheat middlings, oat products, and other feedstuffs commonly used for poultry fleshing. These rations were uniformly successful. In view of the results secured with ration 6, containing peanut meal, which are better than those obtained from the five other rations, it would seem that springs also respond readily to a ration containing suitable protein concentrates.

The results obtained in feeding hens differed from those obtained in feeding immature birds. The gains made by the hens were small and erratic, because of the more variable physical condition in which they were received by the packer. A comparison of the results of the small-scale experiments on peanut meal, soy-bean meal, and meat scrap (Table 5) with those in which the control ration was fed shows that the addition of a protein concentrate does not improve the value of the control ration for hens. As further indicated by the battery experiments (Table 6), hens under packing-house conditions gain about as much on corn meal or cheaper substitutes and buttermilk as on more expensive rations containing protein concentrates.

EFFECT OF LENGTH OF FEEDING PERIOD ON DIFFERENT CLASSES OF BIRDS.

In deciding the number of days that birds should be fed, the packer must consider the rate of growth of the different classes, the desired appearance of the dressed product, and the overhead expense of holding the birds. He is also influenced to a great extent by the market premium offered for certain weights of broilers and roasters. In addition, he should take into account the character of the gains produced. Broilers, springs, and roasters grow rapidly and may be expected to put on muscle and fat tissue during the feeding period, whereas hens put on a much larger proportion of fat. Exact information on this question has been obtained in a series of experiments, details of the results of which are reported in Tables 7 to 10, inclusive. Tables 17, 18, and 19 give a summary of these data.

TABLE 17.—*Character of gains made by different classes of birds fed the control ration.*

Class.	Number.	Water.	Protein.	Lean meat (water and protein).	Fat.	Ratio of protein to fat.	Ratio of lean meat to fat.
		<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>		
Broilers.....	114	4.9	1.2	6.1	3.6	1 : 3.0	1 : 0.58
Springs.....	20	5.3	1.6	6.9	4.8	1 : 3.0	1 : .69
Roasters.....	26	4.9	.7	5.6	4.4	1 : 6.3	1 : .79
Hens.....	80	2.3	.4	2.7	4.4	1 : 11.0	1 : 1.63

The high proportion of fat added by hens explains the feeding results which indicate that protein concentrates are not essential in rations for hens (p. 18).

TABLE 18.—*Gains made in 4, 8, 11, and 14 days by different classes of birds fed the control ration.*

Class.	Number.	Gain in 4 days.		Gain in 8 days.		Gain in 11 days.		Gain in 14 days.
		Percent- age of initial weight.	Percent- age of total gain.	Percent- age of initial weight.	Percent- age of total gain.	Percent- age of initial weight.	Percent- age of total gain.	Per cent- age of initial weight.
Broilers.....	612	12.09	30.10	22.91	57.05	31.34	78.04	40.16
Springs.....	396			17.28	59.81	24.43	84.56	28.88
Roasters.....	336	11.11	49.71	17.29	77.36	20.68	92.53	22.35
Hens.....	456	4.08	34.31	7.75	65.18	9.99	84.02	11.89

The average daily gains made by broilers in the different periods are 3.02, 2.71, 2.81, and 2.94 per cent, respectively. In other words, these broilers continued to add weight very rapidly throughout the feeding period. In 11 days they had made only 78.04 per cent of their total gain. It thus appears that from the standpoint of the amount of gain made, a 14-day feeding period is not too long.

TABLE 19.—*Gains made by broilers during different feeding periods.*

Number of birds.	Marginal gain.	Gain in 4 days.		Gain in 8 days.		Gain in 11 days.		Gain in 14 days.
		Percent- age of initial weight.	Percent- age of total gain.	Percent- age of initial weight.	Percent- age of total gain.	Percent- age of initial weight.	Percent- age of total gain.	Percent- age of initial weight.
96.....	<i>Per cent.</i> 50	17.45	31.18	32.95	58.88	43.81	78.29	55.96
144.....	40 to 50	13.99	31.32	26.25	58.76	36.47	81.64	44.67
180.....	30 to 40	9.98	28.82	18.92	54.63	26.20	76.81	34.63
192.....	20 to 30	6.95	27.37	13.52	53.25	18.87	74.32	25.39
612.....	Average.	12.09	30.10	22.91	57.05	31.34	78.04	40.16

Birds which make small gains in the beginning show small gains at the end, probably because of their physical condition (Table 19).

The average daily gains made by springs in the different periods are 2.14 per cent during the first 8 days, 2.38 per cent from the ninth to eleventh day, inclusive, and 1.48 per cent during the last period. These results show that springs grow very rapidly during the first 11 days, and, although their growth is less rapid during the last period, they still make a fairly good gain.

The roasters made an average daily gain in the different periods of 2.78, 1.55, 0.80, and 0.56 per cent, respectively. Thus their most rapid gain occurred during the first 4 days, the daily gain during the second 4 days being fairly rapid, but very small during the rest of the time.

As previously noted, a large part of the gains made by hens is in the form of fat. Moreover, the gains are small and erratic. The average percentage daily gains made by these hens during the different periods of feeding were 1.02, 0.92, 0.75, and 0.63 per cent, respectively. These small gains, with their high content of fat, indicate that the customary practice of feeding hens for only 6 to 8 days is well founded.

COMPOSITION OF POULTRY BEFORE AND AFTER FEEDING.

The various rations, differing in quality though containing all the essential nutrients, had no consistent effect upon the losses in dressing and chilling nor upon the percentage composition of birds of the same class. Broilers, springs, roasters, and hens, each considered as a class, exhibited marked differences, however. Since a ration consisting of corn meal (40 parts) and buttermilk (60 parts) was used with each experimental ration as a control, more data were accumulated with it than with any of the others. The results obtained with the control ration only, therefore, are presented in detail to show the differences in composition and dressing losses of the four classes of birds.

WEIGHT LOST IN DRESSING.

Table 20 gives a summary of the results of the experiments on the medium-weight breeds, including Rhode Island Reds, Plymouth Rocks, and Wyandottes, to determine the amount lost by the various classes during dressing (Tables 11 and 12).

TABLE 20.—*Weight lost by range and fed birds during dressing.*

Class.	Number.	Average weight.			Percentage of final live weight lost as—				Cooler loss (percentage of dressed weight)
		Final live.	Dressed.	Chilled.	Blood.	Feathers.	Cooler loss.	Total shrinkage.	
Range:		<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>					
Broilers.....	126	30.8	28.5	28.3	4.02	6.67	0.68	11.37	0.76
Springs.....	12	60.4	53.0	52.6	4.38	7.81	.74	12.93	.85
Roasters.....	18	74.7	65.5	65.3	3.85	8.42	.36	12.63	.41
Hens.....	48	79.0	72.1	71.8	3.35	5.33	.31	8.99	.34
Fed:									
Broilers.....	132	41.1	37.1	36.8	4.01	6.45	.87	11.33	.97
Springs.....	24	81.5	71.7	71.4	4.27	7.78	.47	12.52	.54
Roasters.....	28	95.9	85.5	84.9	4.13	6.75	.56	11.44	.63
Hens.....	95	85.4	78.4	78.2	3.27	4.85	.34	8.46	.37

The data presented on springs and roasters are somewhat limited. The total percentage shrinkage for broilers, springs, and roasters was fairly constant both before and after feeding. The shrinkage in the case of hens was much less than that obtained with other types of birds.

DISTRIBUTION OF WEIGHT.

The birds used for obtaining the shrinkage data were dissected, with the results shown in Tables 13 and 14 and summarized in Table 21.

TABLE 21.—*Distribution of weight in range and fed birds.*

Class.	Number.	Percentage of chilled weight.							
		Meat.	Skin.	Crude gizzard fat.	Edible organs.	Eggs.	Total edible.	Offal.	Bones.
Range:									
Broilers.....	114	40.39	7.54	1.31	6.82	-----	56.06	26.19	17.75
Springs.....	12	45.92	8.81	5.95	1.93	-----	62.61	21.65	15.76
Roasters.....	18	44.05	9.48	5.68	3.00	-----	62.21	21.62	16.15
Hens.....	48	38.87	14.68	9.87	4.80	2.38	70.59	18.32	11.10
Fed:									
Broilers.....	56	39.00	10.41	4.21	6.53	-----	60.15	23.81	16.10
Springs.....	8	43.10	13.15	5.53	5.29	-----	67.07	19.96	12.98
Roasters.....	8	40.60	12.61	5.81	5.44	-----	64.46	20.48	15.10
Hens.....	32	37.93	14.67	10.50	5.21	3.09	71.40	18.43	10.18

As they reached the feeding house the range broilers contained on the average 56.06 per cent of edible parts, whereas springs, roasters, and hens contained 62.61, 62.21, and 70.59 per cent, respectively. Thus the proportion of edible portion is much higher in the mature than in the immature birds. After feeding, this difference decreases, and broilers, springs, roasters, and hens have 60.15, 67.07, 64.46, and 71.40 per cent of edible portion, respectively. The results also show that hens have a larger amount of crude gizzard fat than other classes.

COMPOSITION OF RANGE AND FED BIRDS.

The results of the chemical analyses made on the birds, given in detail in Tables 15 and 16, are summarized in Table 22.

TABLE 22.—*Composition of range and fed birds.*

Class.	Number.	Meat.			Skin.			Edible viscera.			Crude gizzard fat.	
		Water.	Fat.	Protein.	Water.	Fat.	Protein.	Water.	Fat.	Protein.	Water.	Fat.
Range:		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Broilers.....	66	74.93	3.02	21.08	56.33	24.97	17.79	74.39	2.73	19.99	31.14	60.04
Springs.....	12	73.13	2.98	22.04	50.01	31.58	17.22	74.13	1.96	20.42	20.26	73.29
Roasters.....	18	73.21	3.59	21.76	48.61	35.02	15.94	74.15	2.66	20.48	22.96	70.98
Hens.....	48	70.34	6.90	21.41	28.70	61.33	9.67	70.99	6.75	19.31	10.23	87.29
Fed:												
Broilers.....	48	72.78	6.15	19.97	40.96	45.80	12.43	74.40	3.58	19.28	15.14	81.65
Springs.....	8	73.07	4.71	20.76	37.68	50.67	11.08	73.68	3.50	18.65	12.45	84.89
Roasters.....	8	72.14	5.99	20.22	40.45	46.68	12.16	73.81	3.78	19.60	12.51	84.95
Hens.....	32	70.22	7.32	21.14	28.54	62.22	9.82	66.88	12.50	17.43	11.21	85.50

The data in Table 22 and the results secured from dissecting the same birds gave the results reported in Table 23, showing the composition of the total edible portions of various classes of chickens before and after feeding.

TABLE 23.—*Composition of total edible portion of chickens before and after feeding.*

Class.	Total edible portion.					
	Water.		Fat.		Protein.	
	Before feeding.	After feeding.	Before feeding.	After feeding.	Before feeding.	After feeding.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Broilers.....	70.87	63.39	7.23	16.91	20.11	17.44
Springs.....	68.07	62.06	12.03	20.26	18.50	17.22
Roasters.....	64.96	61.60	16.55	21.90	17.33	14.42
Hens.....	51.95	50.67	29.26	32.18	17.00	14.94

COMPOUNDING RATIONS.

A great variety of feeds were used in the various rations in order to obtain data on their relative value for poultry fleshing (Table 1). Equally satisfactory results apparently can be obtained by the use of different feedstuffs as well as by the use of different combinations of the same feeds. It is possible to choose from a wide range of feeds which have practically the same fleshing value in a ration. This is fortunate, since it permits the feeder to adapt his ration to market conditions by taking advantage of special prices of certain feeds and also to use feeds available locally.

In the selection of feeds to compose a ration, certain cardinal principles must be remembered. The first consideration is the class of bird to be fed. A growing bird, such as a broiler or spring, requires a ration of quite a different composition from that needed by a mature hen, which responds chiefly to fat production. From the standpoint of the gains made, a simple fattening ration of corn meal and buttermilk is about as good as any other ration for hens.

As chickens are unable to utilize large amounts of roughage in securing their nutrients, milled products, such as corn, wheat, and oats, are used. In this connection it is important to note the fact that coarse oat products do not produce good results. Many investigators have found that the digestive tracts of chickens can utilize only a very small amount of crude fiber.

A well-balanced ration must contain suitable amounts of the following nutrients and food accessory substances: Carbohydrates, fats, proteins, salts (minerals), and vitamins.

Any of the ordinary cereal grains supply the carbohydrates and fats. More care in selection is necessary in securing the protein, salts, and vitamins.

The proteins of the cereal grains are present in too small amounts and are of too poor quality to produce the best results in rations for broilers and springs unless other protein concentrates are added. The results given in this bulletin show that peanut meal protein, as well as soy-bean meal protein, is especially valuable. Ordinarily poultrymen mix the ground feeds into a batter with buttermilk. The proteins of buttermilk are especially valuable, and if used in sufficiently large amounts produce very desirable results. Other protein concentrates are meat and fish scraps, cottonseed meal, coconut meal, and sesame-seed meal.

The seeds of corn, wheat, oats, and other grains lack such mineral substances as calcium, sodium, and chlorine which growing animals require. In the rations where milk (buttermilk or skim milk) is used, these ingredients are supplied in fairly adequate amounts.

During the last few years scientists have found that certain growth-promoting substances called vitamins are essential for all rations. In poultry rations the important vitamin called "Fat-soluble A" is often lacking. It is supplied by the addition of milk. Since the grains are deficient in certain minerals and in fat-soluble vitamin, it is necessary to add to mixtures of grains something containing these essential ingredients. As a rule, the addition of milk supplies these substances.

At present the milk available for poultry-fleshing purposes is largely buttermilk, fresh, condensed, or powdered (Table 1). Until more definite information on the optimum dilution of powdered and

condensed buttermilk for poultry-fattening rations is available it will probably be best to dilute the buttermilk product so that the resulting mixture will have about the same percentage of solids as fresh buttermilk (approximately 8 per cent). In using condensed buttermilk, which contains about 28 per cent of solids, the dilution would be 1 part of condensed buttermilk to $2\frac{1}{2}$ parts of water. In using powdered buttermilk, which has about 90 per cent of solids, the dilution would be about 1 part of buttermilk to 10 of water.

In feeding-house practices the powdered buttermilk is most conveniently used by combining it directly with the dry feed mixture and then pouring in water to make the proper consistency. Adding 15 pounds of powdered buttermilk to 100 pounds of dry feed and mixing with 150 pounds of water gives approximately the same percentage of buttermilk solids as is obtained by using 50 pounds of fresh buttermilk to 40 pounds of dry feed.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1053

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

May, 1922

STUDIES OF CERTAIN FUNGI OF ECONOMIC IMPORTANCE, IN THE DECAY OF BUILDING TIMBERS, WITH SPECIAL REFERENCE TO THE FACTORS WHICH FAVOR THEIR DEVELOPMENT AND DISSEMINATION.

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INTRODUCTION.

There is no means of estimating the total annual loss occasioned by fungi which attack timbers in buildings, but from the evidence at hand it is certain that this loss is very large. This is particularly true in textile mills, paper mills, and canning factories, in which high

¹ The writer wishes to acknowledge his indebtedness in connection with these studies to Prof. L. R. Jones, of the department of plant pathology of the University of Wisconsin, for his interest, encouragement, and criticisms; to Mr. C. J. Humphrey, of the Office of Investigations in Forest Pathology, Bureau of Plant Industry, Madison, Wis., under whose immediate direction this work was undertaken, for general supervision, facilities, and criticisms; and to Mr. F. J. Hoxie, engineer and special inspector for the Associated Factory Mutual Fire Insurance Companies of Boston, Mass., for courtesies tendered in connection with mill investigations and for the loan of photographs.

humidities and moderately high temperatures prevail throughout the year. Such conditions provide a very favorable environment for the development of wood-decaying fungi, and this condition is aggravated by the quality of timber which has been on the market in recent years. The timber formerly used in mill construction consisted in many cases of white pine and white oak, both of which are highly durable woods. In more recent years, however, these timbers have been supplanted largely by southern yellow pine, spruce, and hemlock. High-grade resinous longleaf pine has given good service under exacting conditions, but the inferior grades of pine, often of more rapid growth and frequently containing a high percentage of sapwood, have not proved satisfactory in parts of buildings where the conditions are favorable for decay. Likewise, spruce and hemlock have given poor service under similar conditions. Furthermore, such timbers may be left in the open for protracted periods, exposed to the weather and infection by fungi, or may be put in buildings in a partially seasoned condition, and after a short period replacement is necessary, involving not only the direct expense of repairs but also loss of operating time.

Hoxie (24, p. 2)² reports that 30 cases of rot of greater or less magnitude have come to his attention within three years. He states that "several million feet of lumber were involved, and in some of the worst cases the safety of important structures was menaced. * * * The direct money loss to Mutual members (Associated Factory Mutual Fire Insurance Companies, Boston, Mass.) * * * is undoubtedly many thousand dollars each year, in addition to the increased life and fire hazard from loss of strength and greater combustibility of rotting structural timbers."

The following specific examples from Hoxie's records may be of interest to show the magnitude of the loss. In a Connecticut mill the roofs of weave sheds, built in 1906 and 1909, were so seriously rotted in 1916 that it was estimated that 40,000 feet of plank would be necessary for repairs. The older roof in many places was not safe to walk upon and had settled so that there were hollows supported practically only by the tarred paper. In one Massachusetts cotton mill built in 1900, 85 per cent of the roof planking and a large proportion of the floor supports had rotted and had been replaced by hemlock, in some cases twice between 1908 and 1914. It was found that hemlock, put in green, lasted about two years. It was estimated that over 1,000,000 feet of lumber had been used in the construction of this mill in 1900, at a cost of \$30,000, and the re-

² The serial numbers in parentheses (*italic*) refer to "Literature cited" at the end of this bulletin.

placements during the four years prior to 1914 required about 240,000 feet of lumber at a cost of more than \$6,100. In another Massachusetts cotton mill, one weave shed, built in 1910, by 1916 was affected with decay throughout, and in another shed in the same mill parts of the roof were replaced in 1914, 1915, 1916, and 1917, necessitating the use of 1,000,000 feet of lumber in 1916 and 30,000 feet the next year. A Canadian mill, built in 1908 with beams of supposedly "first-class Georgia longleaf" pine, was thoroughly rotted by 1911, and the beams were replaced by steel.

Blair (2) gives some similar data with regard to the decay of paper-mill roofs. He found that of 80 mills visited, 12 had made renewals just prior to 1920, 17 were to make renewals in 1920, and 24 others would be compelled to make renewals within a short time after that date. Of the roofs which were being replaced in 1920 the service had been 5 to 19 years, with an average of 8 to 10 years.

The foregoing data show that considerable pecuniary losses were occasioned by the action of decay-producing fungi in mills, even when the prices of lumber and labor were comparatively moderate. With the recent high cost of both these factors, the figures become much more impressive. In one Massachusetts cotton mill replacements made during the summer of 1920 in the roof of a weave shed approximately 1,000 by 300 feet cost the owners between \$100,000 and \$125,000.

In Europe the problem of decay in buildings is of long standing and has received considerable attention. Much has been written from several points of view upon the decay caused by *Merulius lacrymans*, including the engineering and legal as well as the mycological and biological factors. Also, the decays caused by *Coniophora cerebella*, *Poria vaporaria*, and species of *Lenzites* have been particularly studied. In this country the study of timber decay in buildings on a comprehensive scale is only beginning, and thus far the work has largely been confined to *Merulius lacrymans* and its relatives and to *Coniophora cerebella*. In mills and other structures in which conditions favorable for fungus growth prevail, other organisms probably do more damage than these, but have as yet received little attention as structural-timber destroying organisms.

Because of the practical importance of the decays caused by these other fungi in textile mills, etc., the writer has undertaken to make some preliminary studies upon certain of them (*Lenzites sepiaria*, *L. trabea*, *Trametes serialis*, *Fomes roseus*, and *Lentinus lepideus*), especially with regard to certain physiological relations of the mycelium, basidiospores, and secondary spores where they occur. Within the time and facilities at his disposal, as much attention as possible has been paid to those factors influencing the intramural dissemination of these forms.

Lenzites sepiaria has been studied as a destroyer of coniferous timbers in buildings by Falck (15) in Europe and out of doors by Spaulding (58) in this country. Its importance in the destruction of mill roofs was suspected by Hoxie (24) in 1915, and since then he and others, including the writer, have found it fruiting quite commonly and doing much damage in such places. (Pl. I, figs. 1 and 2.) *Lenzites trabea* has been reported by Blair (1) as destroying weave-shed roofs. This species, though usually found upon hardwoods in nature, probably occurs more commonly and is more destructive to coniferous lumber under mill conditions than has yet been reported. The writer has found it fruiting upon yellow pine and spruce roofs. (Pl. I, figs. 3 and 4.)

Trametes serialis has been found upon some of the more badly decayed roofs along with other fungi (Pl. I, fig. 5; Pl. II, figs. 1 and 2), but within buildings it is usually upon basement timbers. This fungus generally occurs in the resupinate form and also forms abortive structures.

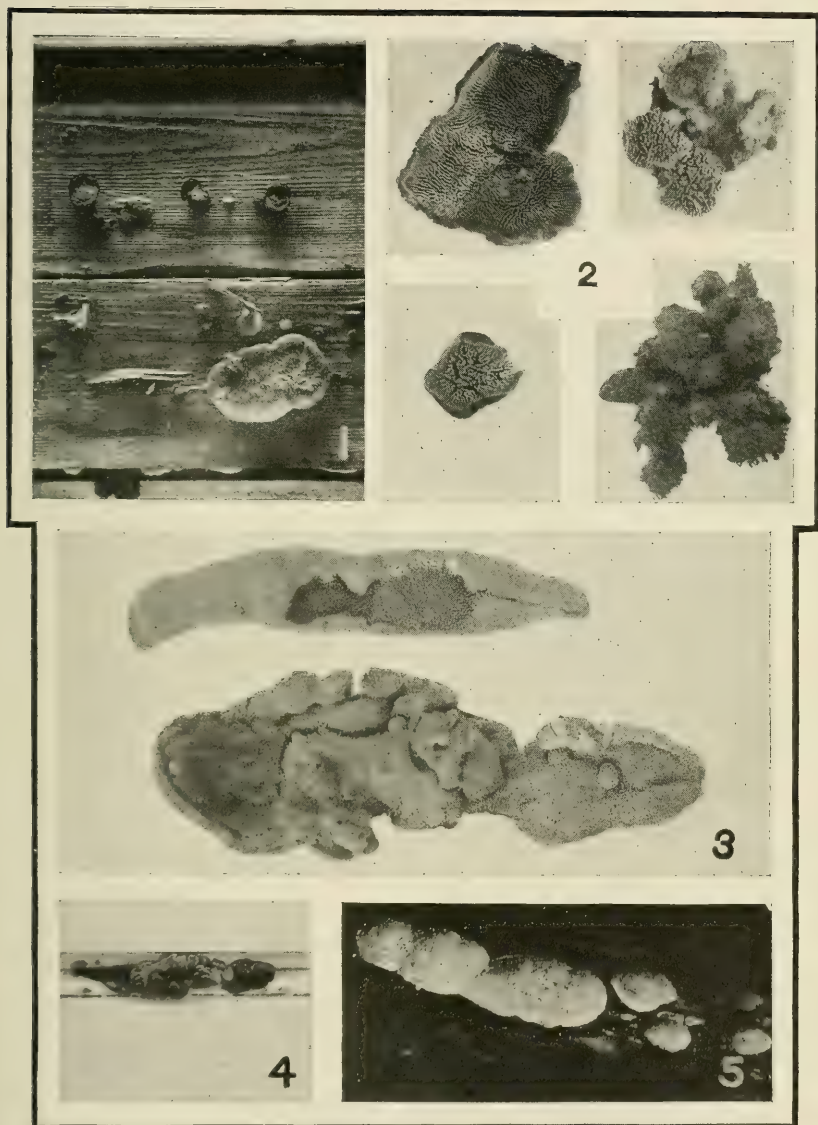
Fomes roseus is found within mills upon beams in moist basements (Pl. II, fig. 5). The annual form is the one of common occurrence, and whether or not the perennial form also occurs is not certain. Many mycologists consider the annual form as a distinct species, *Trametes carnea*.

Lentinus lepideus has been found upon roof timbers under very moist conditions and in basements (Pl. II, figs. 3 and 4). It also occurs in Europe on building timbers (cf. Mez, 35; Falck, 17.) Its destructiveness to structural timber in the open is well known.

BASIDIOSPORES.

SOURCES OF BASIDIOSPORE MATERIAL.

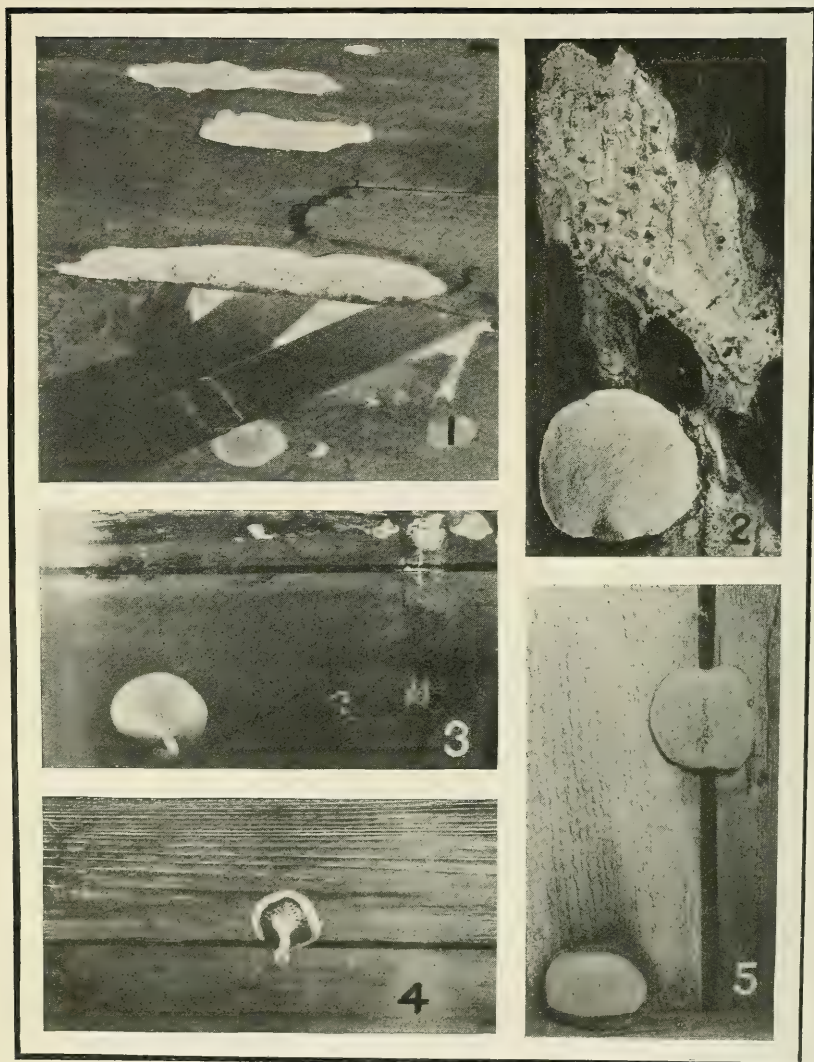
The basidiospores used were obtained for the most part from fruit bodies collected in the field. Those of *Lenzites sepiaria* were from various collections in Wisconsin. The spores of *Lenzites trabea* were obtained from fruit bodies upon pulpwood bolts, collected in Pennsylvania, by F. J. Hoxie. The basidiospores of *Trametes serialis* were obtained from fructifications on some rotten timbers (removed on account of decay) from the pulp-and-paper section in the Forest Products Laboratory and placed in the forest-pathology greenhouse. From two or three small sporophores formed in November, 1919, sufficiently large numbers of spores were obtained to last through two winters of experimentation. Sporophores of the annual form of *Fomes roseus* were collected upon tamarack (*Larix laricina*) logs in Wisconsin and red spruce (*Picea rubens*) in New Hampshire. The spores of *Lentinus lepideus* were obtained from sporophores collected by Mr. Hoxie in a cotton mill in Massachusetts.



FUNGI OF ECONOMIC IMPORTANCE IN THE DECAY OF BUILDING TIMBERS. I.

(Figures 1, 2, and 5 were photographed by F. J. Hoxie.)

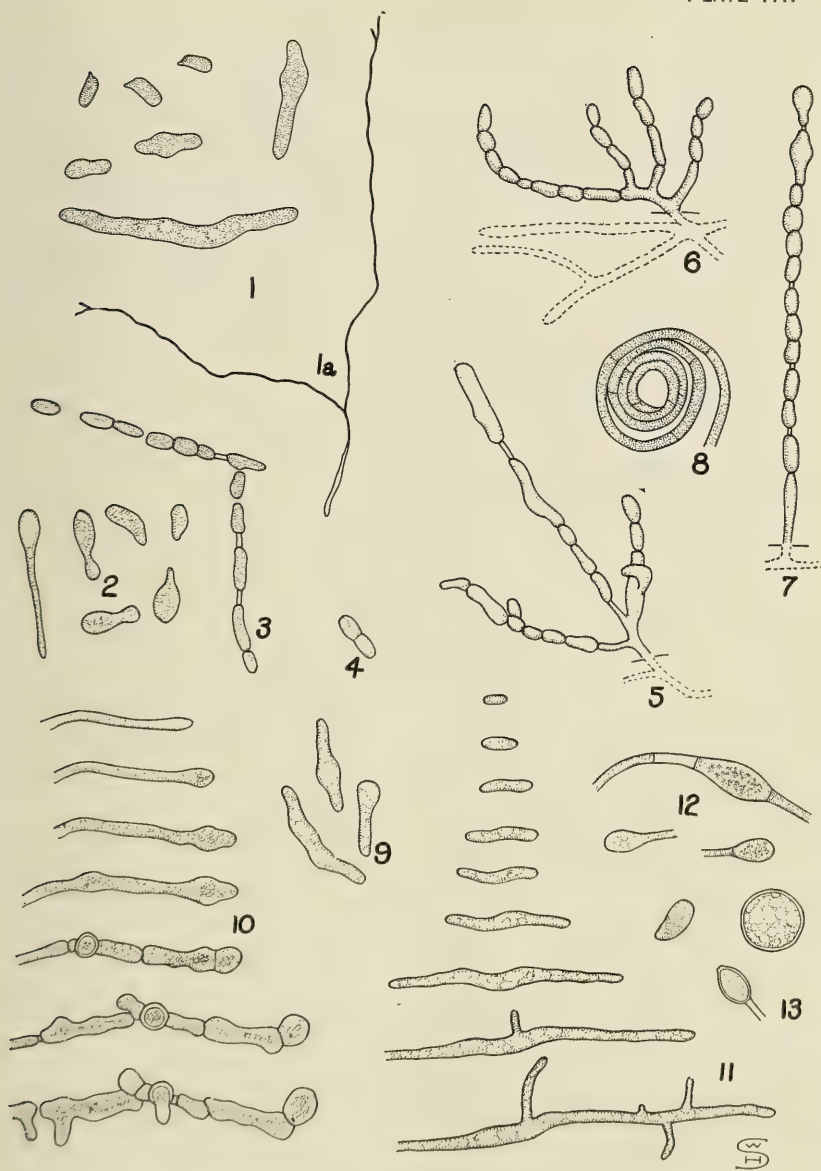
FIG. 1.—Sporophores of *Lenzites sepiaria* on planks of weaved-shed roof which was originally sheathed. ($\times \frac{1}{4}$.) FIG. 2.—Sporophores of *Lenzites sepiaria* from cotton-mill roof. ($\times \frac{1}{4}$.) FIG. 3.—Sporophores of *Lenzites trabea* from cotton-mill roof, same as that shown on roof plank in figure 1. ($\times \frac{1}{4}$.) FIG. 4.—*Lenzites trabea* fruiting body between planks of cotton-mill roof. ($\times \frac{1}{4}$.) FIG. 5.—*Trametes serialis* fruiting upon planks of a roof which was originally sheathed. ($\times \frac{1}{4}$.)



FUNGI OF ECONOMIC IMPORTANCE IN THE DECAY OF BUILDING TIMBERS.—II.

(Photographed by F. J. Hoxie.)

FIG. 1.—*Tramestes serialis* fruiting around belt hole in a weave-shed floor. ($\times \frac{1}{4}$.) FIG. 2.—Fruit body of *Tramestes serialis* on planking in basement of cotton mill. ($\times \frac{1}{4}$.) FIGS. 3 and 4.—Fruit bodies of *Lentinus lepideus* on planking of weave-shed roof which was originally sheathed. ($\times \frac{1}{4}$.) FIG. 5.—*Fomes roseus* fruiting on ceiling planks of basement of cotton mill. ($\times \frac{1}{8}$.)



BASIDIOSPORE STUDIES OF LENZITES SEPIARIA.

(X 475, except 1a, which is X 67.)

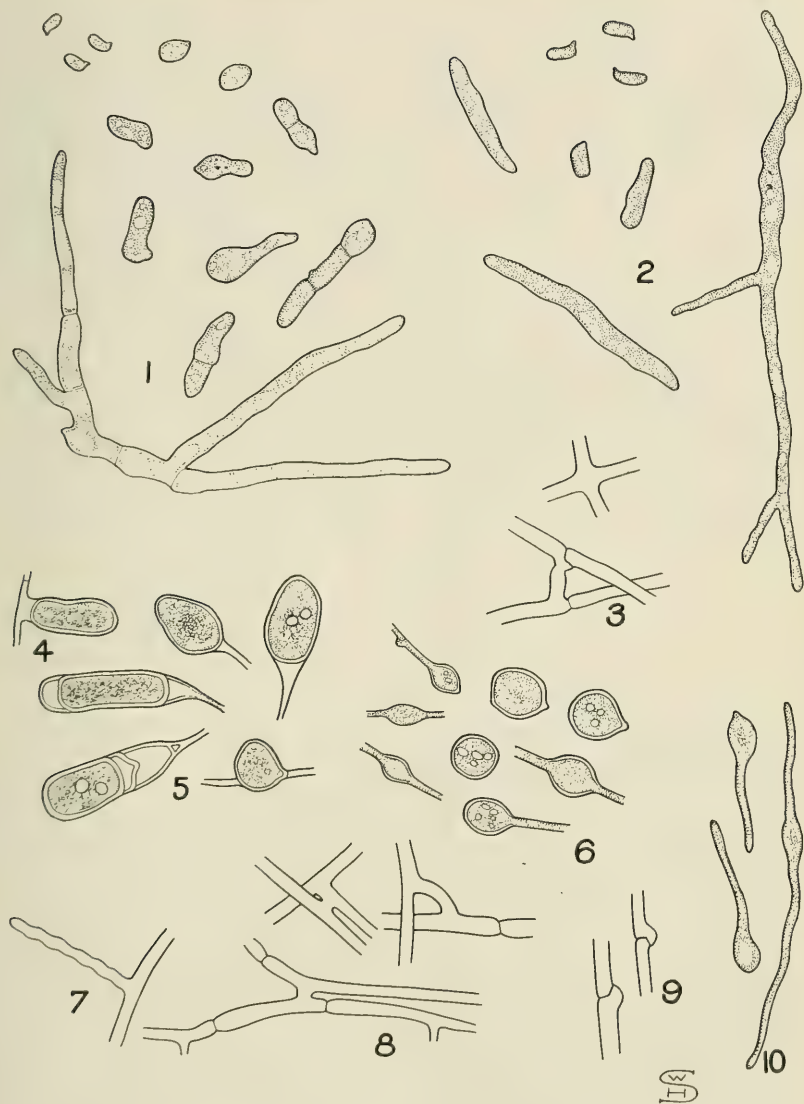
FIG. 1.—Germinating basidiospores on malt agar. FIG. 1a.—Extent of the growth which may take place before branching begins. FIG. 2.—Germinating basidiospores in distilled water. FIG. 3.—Oidia upon submerged mycelium in agar. FIG. 4.—Septate oidium. FIGS. 5, 6, and 7.—Aerial mycelium almost completely broken up to oidal chains. FIG. 8.—Coil in aerial mycelium of older cultures. FIG. 9.—Germinating oidia. FIG. 10.—Successive stages in formation of oidia and one chlamydospore in submerged mycelium in agar with germination of the chlamydospore. FIG. 11.—Stages in the germination of a single oidium. FIG. 12.—Stages in the formation of chlamydospores in submerged mycelium. FIG. 13.—Chlamydospores or chlamydosporelike bodies.



BASIDIOSPORE STUDIES OF LENZITES AND TRAMETES.

(X 475.)

FIG. 1.—Germinating basidiospores of *Lenzites trabea* on malt agar. FIG. 2.—Oidia of *Lenzites trabea* from secondary aerial mycelium on malt agar. FIG. 3.—Stages in formation of chlamydospores upon submerged mycelium of *Lenzites trabea* in malt agar. FIG. 4.—Chlamydospores and chlamydosporelike bodies of *Lenzites trabea* upon submerged mycelium in malt agar, one of them germinating. FIG. 5.—Germinating basidiospores of *Trametes serialis* on malt agar. FIG. 6.—Stages in formation of chlamydospores of *Trametes serialis* on malt agar. Note contraction of protoplasm and formation of walls. FIG. 7.—Chlamydospores of *Trametes serialis* from submerged mycelium in malt agar. FIG. 8.—Chlamydospore of *Trametes serialis* on aerial mycelium in malt agar tube, showing old walls. FIG. 9.—Germinating chlamydospores of *Trametes serialis* on malt agar. FIG. 10.—Irregular hypha from tertiary mycelium of *Trametes serialis* at top of agar slant culture. FIG. 11.—Sprouting of clamp of *Trametes serialis*. FIG. 12.—Clamps, anastomosing of hyphae, and other irregularities from agar slant cultures of *Trametes serialis*.



BASIDIOSPORE STUDIES OF FOMES AND LENTINUS.

(X 475.)

FIG. 1.—Germinating basidiospores of *Fomes roseus* on malt agar. FIG. 2.—Germinating basidiospores of *Lentinus lepideus* on malt agar. FIG. 3.—Anastomosing of hyphae, one from clamp, of *Lentinus lepideus*. FIG. 4.—Chlamydospore from aerial tertiary mycelium of *Lentinus lepideus* on malt agar. FIG. 5.—Chlamydospores of *Lentinus lepideus* on submerged mycelium, in malt agar. FIG. 6.—Mature and immature chlamydospores from colored mycelium overgrowing gills of sporophore of *Lentinus lepideus*, collected in a Massachusetts cotton mill. FIG. 7.—Wavy branch from aerial mycelium of malt agar culture of *Lentinus lepideus*. FIG. 8.—Types of anastomosing of mycelium of *Lentinus lepideus* on malt agar. FIG. 9.—Clamps from aerial mycelium of *Lentinus lepideus* on malt agar. FIG. 10.—Basidiospores of *Lentinus lepideus* germinating upon red spruce.

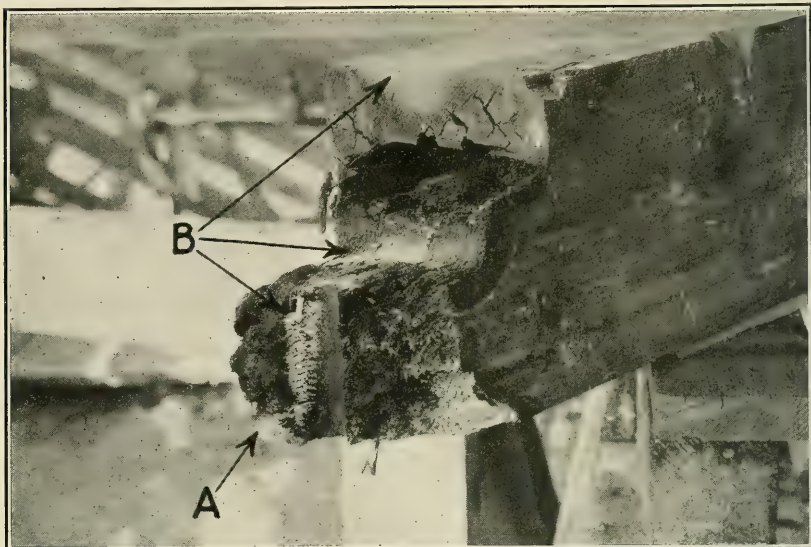


FIG. 1.—DISSEMINATION OF BASIDIOSPORES OF *TRAMETES SERIALIS* BY IMPERCEPTIBLE CURRENTS OF AIR IN A CLOSED PIT.

The sporophore at *A* naturally dropped spores downward, but in the closed pit there were air currents of sufficient magnitude to carry the spores upward to be deposited at points marked *B*. ($\times \frac{1}{2}$.)

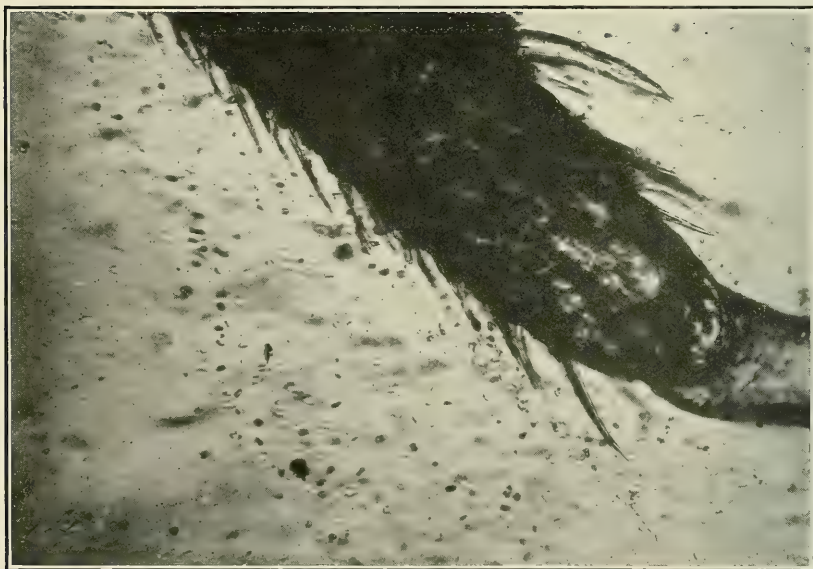


FIG. 2.—DISSEMINATION OF *TRAMETES SERIALIS*.

Basidiospores of *Trametes serialis* on the leg of a sow bug caught in condensation water beneath the sporophore in fungus pit at Madison, Wis. ($\times 250$.)

METHODS USED IN THE BASIDIOSPORE STUDIES.

The basidiospores used in the tests were collected and kept on sterilized glass slides, as a rule, although the spores of *Lentinus lepideus* were collected upon sterilized black paper. The spore prints were obtained in the usual way, care being taken to prevent moisture from collecting upon the prints for it was found early in the work that such condensation water affected the viability of the spores. The prints were then preserved in Petri dishes in an ice box in which the temperature was 12° to 16° C., and the relative humidity 40 to 45 per cent. For the general purposes of experimental work the glass slides for spore prints were preferred to the black paper because of ease of manipulation and cleanliness.

All spore germination tests were made upon the surface of agar, usually in Van Tieghem cells. The germination of spores upon the surface of the cooled agar had certain advantages. The question of the oxygen supply available for the spores was obviated. It was easier to count percentages of germinated spores when they were all in one plane. And besides there was no danger of subjecting the spores to unfavorable temperatures, as may be the case when they are introduced into melted agar. A temperature only slightly too high, produced either by a hot needle or hot agar, materially reduces the percentage of germination. For purposes such as drawing, photography, or examination by the higher powers of the microscope, sowings of spores were made upon thin films of agar poured on sterile slides kept in moist chambers under sterile conditions. The agar media used for all experimentation contained 2 per cent of agar with 2½ per cent of malt extract, filtered through filter paper in a Büchner filter and autoclaved 30 minutes at 8 pounds pressure. Occasionally, for the taking of photomicrographs, water agar (malt extract omitted) similarly filtered was used because of its greater transparency. Unless otherwise specified, all germination tests were run in an incubator at 28° C.

GERMINATION OF THE BASIDIOSPORES.

The germination of the basidiospores of the species under consideration presents no features unusual for hyaline hymenomycetous spores. All of them swell more or less in the process. The spores of *Lenzites sepiaria*, *L. trabea*, and *Lentinus lepideus* swell to very little more than the diameter of the germ tube, so that they are not very conspicuous in the thalli of the germinated spores (Pl. III, fig. 1; Pl. IV, fig. 1; Pl. V, fig. 2). *Fomes roseus* spores swell considerably (Pl. V, fig. 1), but those of *Trametes serialis* swell much more (Pl. IV, fig. 5). These latter spores swell to a large globular body of many times the volume of the original spore before the germ

tubes are formed, and the spore is always very conspicuous in the thallus. The germ tubes of *Fomes roseus* have been more vacuolate than those of the other species.

The spores of all species germinate readily upon all nutrient media and upon red spruce (Pl. V, fig 10, for *Lentinus lepideus*). In water the results were as erratic as those reported by other workers with spores of basidiomycetes. The spores germinated in tap water, although the proportion ranged from less than 1 to 55 per cent in distilled water germination took place occasionally (Pl. III, fig. 2, for *Lenzites sepiaria*). The rate of germination was usually low, although sometimes as high as 50 per cent. Even with fresh spores germination could not always be induced in distilled water.

EFFECT OF TEMPERATURE UPON THE GERMINATION OF THE BASIDIOSPORES.

In these studies both percentage and rapidity of germination have been noted. It is interesting to know the rate at which these spores germinate, but of the two criteria percentage would be likely to give the best indication of the effect of various environmental conditions. From the point of view of infection of structural timbers, if a large percentage of spores will germinate over a wide range of temperatures it makes little difference whether it takes three or four days for them to germinate at 10° C. (49° F.) or only 16 hours at the optimum rate of germination. The chances for infection, however, are somewhat greater at the optimum temperatures, because of the somewhat larger number of spores capable of germinating. The percentages given herewith have no absolute value, either for the individual species or for purposes of comparison between species. It is possible that spores collected from different fruit bodies of the same species of different degrees of maturity, from different climatic conditions, and under different conditions of casting might give varying percentage values. It is certain that age is a factor. Hence, that one species should give 75 per cent germination at the optimum temperature and another only 40 per cent does not mean that the spores of the one are inherently more vigorous than those of the other. In the data presented germination is taken to consist in a germ tube at least as long as the swollen spore. The data for the effect of temperature upon germination are given in Table 1 and in figure 1.

For *Lenzites sepiaria* with certain variations tests showed that between 12° and 40° C. (53° and 104° F.) there was little difference as to the effect of temperature upon the percentage of germination if the time element was disregarded. The optimum for rate of germination was between 32° and 36° C. (89° and 97° F.), an optimum somewhat lower than that obtained by Falck. At 40° C. (104° F.) the results varied with the age of the spores. Those a few months

old gave only sparing germination, while fresh ones germinated about as well as at 36° C. (97° F.) but more slowly. Falck (15,

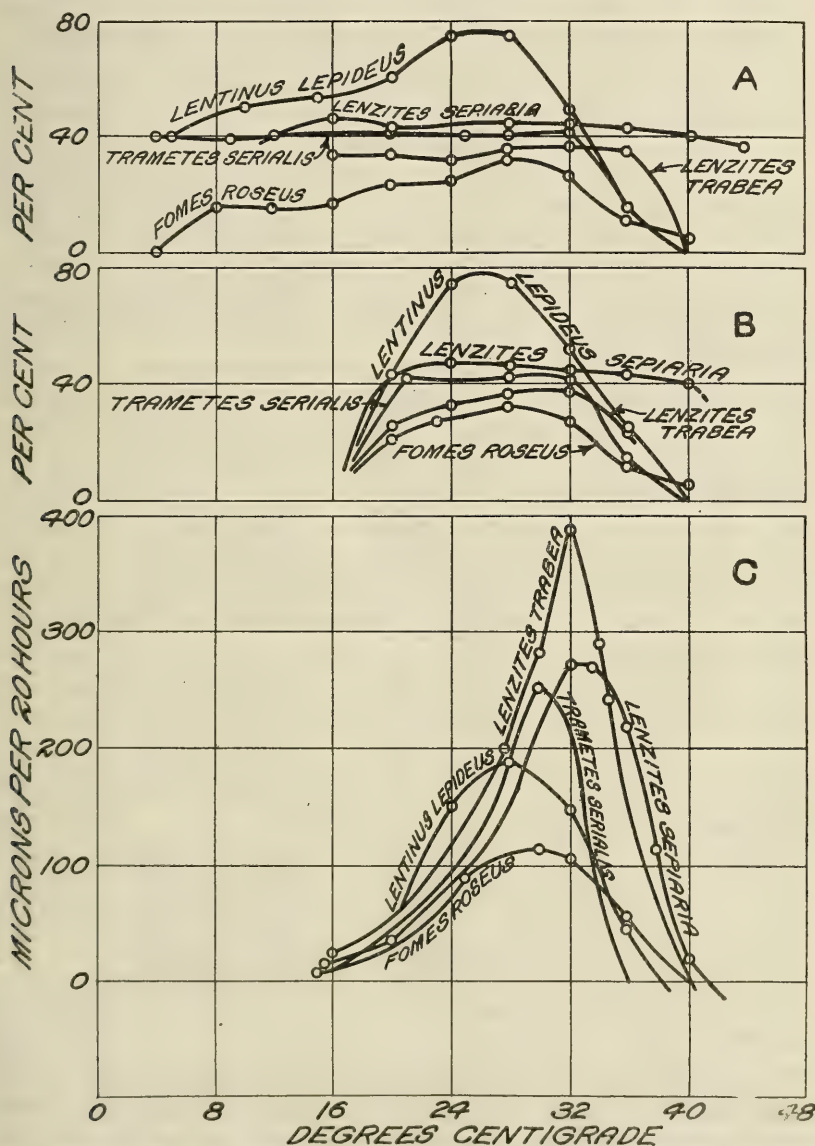


FIG. 1.—Effect of temperature upon the germination of the basidiospores upon malt agar. A, Maximum percentage obtained, disregarding the time element; B, percentage of germination in 20 hours; C, rate of growth of the thalli in 20 hours (shown in microns). These values are not to be considered as absolute for any of the species, nor are they necessarily comparable species with species, but they represent the values obtained with the spores available.

pp. 98–99) found that they germinated at 42° C. (107° F.) but not at 46° C. (115° F.), with most rapid germination at 34° C. (93° F.).

The lowest temperature tried by him was 10° C. (49° F.), and the spores germinated at that temperature.

TABLE 1.—*Relation of temperature to the germination of basidiospores.*

Species and temperature.	Germination.		
	Per cent.	Taken in—	Rate.
<i>Lenzites sepiaria</i> (spores 3 days old):			
12° C.	40	4 days.....	Germinated in 2 days.
15° C.	46	...do.....	14 to 18 μ in 20 hours.
20° C.	43	24 hours.....	30 to 40 μ in 20 hours.
28° C.	45	20 hours.....	105 to 175 μ in 20 hours.
32° C.	44	...do.....	210 to 350 μ in 20 hours.
36° C.	43	...do.....	180 to 250 μ in 20 hours.
40° C.	40	36 hours.....	Swelling and beginning of tubes in 36 hours.
<i>Lenzites trabea</i> (spores fresh):			
16° C.	33	3 days.....	12 to 21 μ in 20 hours.
20° C.	34	48 hours.....	43 to 73 μ in 20 hours.
24° C.	32	36 hours.....	90 to 143 μ in 20 hours.
28° C.	36	26 hours.....	160 to 245 μ in 20 hours.
30° C.	37	...do.....	210 to 350 μ in 20 hours.
32° C.	37	26 hours.....	310 to 450 μ in 20 hours.
36° C.	35	...do.....	175 to 200 μ in 20 hours.
40° C.	(a)	36 hours.....	Just beginning in 20 hours.
<i>Trametes serialis</i> (spores 8 days old):			
3° C.	40	12 days.....	7 to 32 μ in 12 days.
9° C.	39	10 days.....	15 to 25 μ in 8 days.
15° C.	41	6 days.....	160 to 300 μ in 3 days.
20° C.	41	42 hours.....	31 to 68 μ in 20 hours.
25° C.	40	24 hours.....	60 to 80 μ in 20 hours.
28° C.	41	...do.....	87 to 125 μ in 20 hours.
32° C.	43	...do.....	210 to 235 μ in 20 hours.
36° C.	15	...do.....	Just beginning in 20 hours.
40° C.	0	3 days.....	
<i>Fomes roseus</i> (spores fresh):			
4° C.	1	1 month.....	Germination in 1 month.
8° C.	15	9 days.....	Germination in 9 days.
12° C.	15	3 days.....	Germination in 3 days.
16° C.	17	...do.....	Just beginning in 20 hours.
20° C.	23	2 days.....	12 to 36 μ in 20 hours.
24° C.	24	24 hours.....	57 to 98 μ in 20 hours.
28° C.	33	...do.....	98 to 120 μ in 20 hours.
32° C.	26	...do.....	84 to 121 μ in 20 hours.
36° C.	12	...do.....	Just beginning in 20 hours.
40° C.	5	...do.....	
<i>Lentinus lepideus</i> (spores 7 months old):			
5° C.	40	10 days.....	Thalli up to 43 μ in 23 days.
10° C.	50	5 days.....	25 to 40 μ in 5 days.
15° C.	54	3 days.....	50 to 80 μ in 5 days.
20° C.	60	2 days.....	43 to 61 μ in 20 hours.
24° C.	75	21 hours.....	133 to 174 μ in 20 hours.
28° C.	75	18 hours.....	150 to 221 μ in 20 hours.
32° C.	50	16 hours.....	124 to 178 μ in 20 hours.
36° C.	6 to 25	24 hours.....	42 to 60 μ in 20 hours.
40° C.	0	...do.....	Just beginning in 20 hours.

a Less than 1 per cent.

The basidiospores of *Lenzites trabea* germinated in small percentages at 40° C. (104° F.), at high percentages from 24° to 32° C. (75° to 89° F.), and most rapidly between 28° and 32° C (82° and 89° F.).

The spores of *Trametes serialis* germinated at the lowest temperature tried, 3° C. (36° F.), but not at 40° C. (104° F.). The general optimum for percentage was between 20° and 32° C. (68° and 89° F.), with the most rapid germination between 30° and 32° C. (86° and 89° F.).

Fomes roseus spores germinated most rapidly between 28° and 32° C. (82° and 89° F.), while the percentage was highest between 24° and 32° C. (75° and 89° F.).

For *Lentinus lepideus* the largest percentage of germination was between 25° and 28° C. (76° and 82° F.), although 40 per cent germinated in 16 hours at both 20° and 32° C. (68° and 89° F.). The percentage for the lower temperatures down to 5° C. (40° F.) was 40 to 50 per cent. These spores germinated in 10 hours at 28° C. (82° F.) and in 18 to 20 hours at 24° C. (75° F.).

Falck (16, p. 258) has suggested that the percentage optimum for germination of basidiospores is to a certain extent a matter of simultaneous germination, and that as the optimum is approached there is a greater number of simultaneously germinating spores. Inasmuch as all the spores do not germinate at the same time, particularly at the lower temperatures, care should be taken to give the viable spores opportunity to germinate. According to Falck, the more favorably situated spores germinate first, but there is also the possibility that the less favorable temperatures affect the protoplasm of the individual spores differently and thus cause differences in rapidity of germination. In the case of *Lentinus lepideus* (Table 1) at 5° C. only a small percentage had germinated in 5 days, 30 per cent in 8 days, and 40 per cent in 10 days. Care must be taken also that the percentage counts are not made at intervals too great to keep track of what is going on at the lower temperatures. Whereas basidiospores of *L. lepideus* germinated 30 per cent in 8 days and 40 per cent in 10 days at 5° C., in 23 days in the same set of duplicate hanging drops only 22 per cent of living thalli could be counted. The explanation seems to be that of the 40 per cent which had germinated, a certain number of the germinated spores could not stand the low temperature and had died and become invisible on the agar substrate.

EFFECT OF LIGHT UPON THE GERMINATION OF THE BASIDIOSPORES.

Hoffmann (21, p. 32) found that spores of *Agaricus campestris* germinated sooner in the light than in the dark and that bright sunlight did not hurt the spores of several imperfect fungi and some rusts. Ferguson (19, p. 21) found, however, that the spores of *Agaricus campestris* would not germinate in direct sunlight or in diffused light in four weeks, even under the special conditions furnished by her for the germination of these refractory spores. In the experiments by Buller (8, pp. 24-26) spores of *Daedalea unicolor* and *Schizophyllum commune* germinated after exposure to direct sunlight for periods up to eight hours, but the germination of these was slower than of those kept in the dark, and the percentage of

germination was lower. In three days the mycelium from the spores kept in the dark was more advanced than that from the spores exposed to the sunlight. Rhoads (47, p. 66) noted no difference in the time required for the germination of the spores of *Polyporus pargamensis* in the presence or absence of diffused light.

The writer tested the action of both diffused light and direct sunlight upon dry spore prints for a possible killing effect and upon spores on agar during germination for a possible inhibiting effect. Duplicate spore prints upon slides or agar plates with spores for germination were placed side by side in the light, supported upon a nonconducting frame, with one of the pair inclosed in a box made light-tight and yet allowing for ventilation, in order to prevent the heating of the slides or Petri dishes. Experiments upon the effect of diffused light acting during germination were started in the early morning and allowed to run until the next night, in order to have the spores under the influence of light while starting to germinate and to obtain the maximum amount of daylight.

It was found that two days of diffused light in an east window during the winter had no appreciable effect upon the percentage of germination or upon the rapidity of germination, although it hindered the subsequent growth of the thalli somewhat.

It was found also that diffused light acting upon dry spore prints for 10 days had no appreciable effect on the viability of the spores.

Direct sunlight acting upon the basidiospores upon agar inhibited germination during exposure, as compared with controls. Spores exposed to direct sunlight for one day would germinate upon being set aside in the dark, but those exposed for two days showed little or no germination.

The tests on the killing effect of direct May and June sunlight upon dry spores were carried on chiefly with the basidiospores of *Lenzites sepiaria* and *L. trabea*, with two tests on the spores of *Trametes serialis* and *Lentinus lepideus*. When the tests were properly checked so as to obviate as far as possible the effect of atmospheric conditions, the results were as consistent as could be expected.

In general, it was found that one day of exposure did not affect the viability of the spores materially. An exposure of two days usually reduced the percentage of germination considerably, sometimes entirely, while three days' exposure usually killed most of the spores. Only those tests were considered in which the control slides showed unreduced germination at the end of the test, for it was found, as will be shown later, that certain atmospheric conditions greatly reduced the viability of the spores.

Two experiments were tried to see if the germ tubes showed any phototropic reactions. The slides of Van Tiegham cells were placed

in a photographic plate box with a slit 5 millimeters wide cut in one of the narrow sides. The box was set up with the slides inside, the slit toward an east window. In the first test the cells were inoculated at night and examined in 24 hours. In the second the inoculations were made in the morning and examined in 24 hours. In neither set did the germ tubes of any of the four species, *Lenzites sepiaria*, *L. trabea*, *Trametes serialis*, *Lentinus lepideus*, show any phototropic response. The tubes pushed out of the ends of the swollen spores as usual, and their subsequent course was as irregular as in the dark or in diffused light, where checks were placed.

RETENTION OF THE VIABILITY OF THE BASIDIOSPORES.

Falck (15, pp. 99-100) expressed the opinion that in nature the length of time the spores of wood-destroying fungi could retain their viability was a matter of little moment, inasmuch as most of them had the ability at least to hold over the longest period of drought. Rumbold (49, p. 102) found that 0.25 per cent of the spores of *Coniophora cerebella* germinated after one year and six months under laboratory conditions. Falck (15, p. 100) reported that the spores of *Lenzites sepiaria* 6 months old germinated like fresh spores, but from that time there was a steady decrease in the percentage of germination. In a year and seven months only a very few germinated, and none in two years. The spores of *Merulius lacrymans* he found (16, p. 234) to be longer lived. Spores 1 year old germinated normally; after three years 25 per cent germinated; and after five or six years spores sprayed with 2 per cent malic acid, dried immediately, and then put in a moist chamber at 15° C. gave some germination. Rhoads (47, p. 70) showed that the spores of *Polyporus pargamensis* kept on waxed paper in a desk in a warm room remained viable for 10 months, but not for 12. At the end of that time there was swelling, but no germination.

The question as to the maximum period of retention of vitality resolves itself into how best to preserve spores under laboratory conditions. It has been shown by Falck (15, p. 100) and Möller (36, p. 38) that spores are best preserved when taken dry and kept dry, and that spores in a moist atmosphere soon deteriorate. Thick prints also undoubtedly keep better than thin ones. Just what combination of dryness and temperature is more favorable for prolonging the life of the spores is not certain. The writer has kept spores best in an ice box, where the temperature was found to be 12° to 15° C. and the relative humidity 40 to 45 per cent. A very humid atmosphere is harmful, as are also very dry conditions at higher temperatures. Whether very dry and cool conditions would be better than a moderate amount of moisture in the air at the same temperature is not known.

The longest periods during which any spores of the species studied have given germination are shown in Table 2.

TABLE 2.—*Maximum period of retention of viability of the basidiospores of Lenzites sepiaria, Lenzites trabea, Trametes serialis, Fomes roseus, and Lentinus lepideus.*

Species and source of sporophores.	Period of retention of viability.		Germination.
	Dates.	Spores germinated after—	
Lenzites sepiaria: Madison, Wis., November, 1917.	Apr. 13, 1918, to Feb. 10, 1921.	2 years 10 months a....	25 per cent.
L. trabea: Cotton mill, Centerville, R. I., February, 1920.	February, 1920, to February, 1921.	1 year a.....	60 per cent.
Trametes serialis: Madison, Wis., November, 1916.	November, 1916, to February, 1921.	4 years 3 months a....	2 per cent.
Fomes roseus: Wisconsin, June, 1917, on tamarack (Larix).	June, 1917, to December, 1918.	18 months b.....	Few in thousands.
Minnesota, June, 1919, on Prunus.	June, 1919, to Feb. 10, 1921...	1 year 8 months a.....	Less than 1 per cent.
Lentinus lepideus: Cotton mill, New Bedford, Mass., July 5, 1918.	July 5, 1918, to Feb. 10, 1921...	2 years 7 months b....	Do.

a These figures refer to the last tests; further tests may show that these spores survived longer periods.

b These spores gave no germination in 20 months.

VIABILITY OF BASIDIOSPORES DRIED AT DIFFERENT TEMPERATURES.

Because of the lack of sufficient quantities of basidiospores, tests upon the effect of drying are neither complete nor entirely satisfactory, because only one series has been conducted. It is to be expected that the age of the spores will make some difference in their resistance to drying and that, as pointed out previously, individual casts of spores may vary, hence the tests here reported are only indicative. For example, it will be noted (Table 3) that spores of *Trametes serialis* 2 years old succumbed sooner at 28° C. (82° F.) than at 32° C. (89° F.).

At 28° and 32° C. the spores of *Trametes serialis* and *Lentinus lepideus* of the ages given ceased to germinate after an exposure of about 10 weeks to dry incubator conditions. At 36° C. (97° F.) it took about a month to kill all or most of the spores.

At 40° C. (104° F.) it will be noted (Table 4) that in one week there was a decided drop in the percentage of germination of the spores of the three species tested. Those of *Fomes roseus* did not survive one week at 40° C. In two months, however, the spores of *Lenzites sepiaria* were not all killed, nor those of *Trametes serialis* in six weeks. These spores were fresh, while those in the tests at 36° C. were not absolutely fresh.

TABLE 3.—Effect of drying at different temperatures upon the germination of basidiospores of *Trametes serialis* and *Lentinus lepideus*.

Drying temperature.	Trametes serialis (spores 2 years old).			Lentinus lepideus (spores 5 months old).		
	Period.	Germination (per cent).		Period.	Germination (per cent).	
		Dried.	Check.		Dried.	Check.
At 28° C. (82° F.).....	Beginning.....	50	50	Beginning.....	50	50
	1 week.....	30	50	2 weeks.....	51	50
	2 weeks.....	18	50	4 weeks.....	24	49
	4 weeks.....	1	50	6 weeks.....	28	50
	6 weeks.....	0	50	8 weeks.....	14	52
	.....	.....	.....	9½ weeks.....	0	50
At 32° C. (89° F.).....	Beginning.....	50	52	Beginning.....	50	50
	1 week.....	1	48	2 weeks.....	53	49
	2 weeks.....	1	51	4 weeks.....	22	48
	4 weeks.....	1	51	6 weeks.....	17	51
	6 weeks.....	1	50	8 weeks.....	5	42
	9½ weeks.....	0	0	9½ weeks.....	0	51
At 36° C. (97° F.).....	Trametes serialis (spores 10 days old).			Lentinus lepideus (spores 7 months old).		
	Beginning.....	99	99	Beginning.....	32	32
	10 days.....	8	45	10 days.....	20	21
	18 days.....	1	20	18 days.....	3	20
	28 days.....	0	20	28 days.....	(1)	20
						

¹ Less than 1 per cent.

TABLE 4.—Effect of drying basidiospores of *Lenzites sepiaria*, *Trametes serialis*, and *Fomes roseus* at 40° C.

Drying temperature.	Lenzites sepiaria (spores fresh).			Trametes serialis (spores fresh).			Fomes roseus (spores 5 months old).		
	Period.	Germination (per cent).		Period.	Germination (per cent).		Period.	Germination (per cent).	
		Dried.	Check.		Dried.	Check.		Dried.	Check.
40° C. (104° F.)..	Beginning.	38	38	Beginning.	76	75	Beginning.	38	30
	1 week.....	13	39	1 week.....	14	75	1 week.....	0	26
	20 days.....	8	39	6 weeks.....	7	70	.....	.....	.....
	2 months.....	3	38	.....	.....	.....	.....	.....	.....

EFFECT OF ALTERNATE WETTING AND DRYING UPON THE VIABILITY OF THE BASIDIOSPORES.

In removing spores from a spore cast on a glass slide, a large number of the spores dislodged from the slide by the water are left behind. From the point of view of economy of material the question naturally arose as to whether or not these spores wet once and allowed to dry out again were capable of normal germination. A number of tests made upon different lots of spores of varying ages from fresh ones to those a few weeks old seem to show that alternate wetting and drying reduce the percentage of viable spores. In one

case the reduction in the percentage of germination was only from 48 to 37 per cent. In others, it was from 70 to 20 or 30 per cent. In most of the tests, however, the reduction was more pronounced, resulting in no germination or only 2 to 5 per cent. The lack of uniformity in results is probably to be explained by differences in the condition of the spores, length of time they remained wet, and time taken to dry.

It was found in the preliminary experiments of the effect of light upon germination that spore prints left out of doors over night, even though protected from falling water, lost their viability after one or two nights and days. Similar spores retained their normal viability, however, when protected over night in a closed desiccator (without drying chemical). Spores of all five fungi studies behaved in the same manner. The explanation is probably to be found in the diurnal changes of atmospheric humidity.

OBSERVATIONS ON THE CASTING OF THE BASIDIOSPORES.

Buller (8, p. 111) has shown that fruit bodies of *Lenzites sepiaria* can be revived and made to cast spores after four months of drying. Falck (15, p. 66) revived them after one year and nine months of drying. The writer collected some sporophores of this plant from prostrate white pine in Wisconsin in June, 1919. The weather had been sufficiently moist to allow the formation of an abundance of sporophores and it is not known how long any of them had been casting spores. The collections were taken inside and left for a day. They were then moistened over night and placed upon glass slides the next day for spore casting. At night the prints were collected and the sporophores allowed to dry on a table in the room until the night of the second day following, when they were again moistened for another cast the next day. With this rotation of 48 hours of drying in the room, 12 hours of wetting, and then 12 hours of casting, spore prints were obtained six times. The seventh time the sporophores failed to produce visible prints. Several sporophores collected when frozen in November, 1919, and then kept in an ice box for one month were treated in a similar manner in the laboratory. Visible casts were obtained four or five times from single sporophores, even through the summer of 1920.

Sporophores of *Lenzites sepiaria* kept in the laboratory were revived after 15 months and usable prints obtained, but the same ones would not revive after two years. Sporophores which had overwintered out of doors during 1919-20 (one set in Providence, R. I., and the other in northern Vermont) were made to cast spores in early March and April, 1920.

Sporophores of *Lenzites trabea* have been revived after six to nine months, but repeated castings have not been obtained from the same

sporophores. Sporophores collected near Providence which had overwintered were made to cast spores abundantly in April, 1920.

The fruit bodies of *Trametes serialis* studied were those, already referred to, which were formed in the fungus pit in the forest-pathology greenhouse at Madison, Wis. This fungus fruited on the timbers each fall from 1916 to 1919. It is not known whether fruiting occurred at other times. The sporophores were few in number and the total hymenial surface never exceeded 150 square centimeters. These small fruit bodies, however, liberated large numbers of spores. Figure 1 of Plate VI shows visible prints from one small one during two or three days on a vertical surface where the hymenial surface was not large, and it is likely that only a small part of the spores cast were caught on the surfaces shown. In a single day resupinate sporophores cast thick crusts of spores on glass slides and continued to do so for several days. All of the basidiospores of *Trametes serialis* used in this work for three winters came from heavy casts made in the fall of 1916. Three fruit bodies formed in November, 1919, were kept under observation in order to obtain some idea as to the length of the casting period. Fruiting was first noted on November 18 and casting had already begun. It continued for 15 consecutive days.

These fruiting bodies of *Trametes serialis* were formed in the dark. The largest one was kept in the dark for the whole period of 15 days, and the two smaller ones were put in a moist chamber in the light in the laboratory. Spores were cast abundantly in both places. On the fifteenth day the sporophores began to turn brown at the edges and shrivel up, although in an atmosphere practically saturated, and these parts became attacked by molds. On the next day the browning and shriveling had proceeded farther and the molds had spread. The simultaneous cessation of casting and encroachment of molds was striking, as was the absence of molds on the delicate hymenia during the 15 days of sporulation under very humid conditions. The same phenomenon was observed in the tests on the casting of spores by *Lenzites sepiaria*, as molds did not make their appearance until after the sporophores had ceased to cast spores. The spent fruit bodies of *Trametes serialis* left in the fungus pit soon disappeared. When dried artificially, they became very thin, fragile, and distorted, but in the pit they disintegrated through attack by molds and consumption by sow bugs.

The writer has never succeeded in obtaining basidiospores from the perennial form of *Pomes roseus*. From the annual form spores are usually cast sparingly. In the laboratory visible prints have been obtained only occasionally. Attempts to obtain prints out of doors were made at Crawfords, N. H., in September, 1919, during a pro-

tracted period of moist weather, but efforts with many sporophores at different locations resulted in little success. Sporophores of the annual form of *F. roseus* were revived to cast a few spores after 20 months in the laboratory.

No data are at hand relative to the length of the spore-casting period of *Lentinus lepideus*. Sporophores of this fungus will sometimes revive in moist atmosphere after having been kept dry a few months (six months at least) and will cast spores. The chief difficulty in obtaining prints is that molds growing on the fleshy pilei contaminate them. A single fruit body will liberate a large number of spores in a short time. A large one, about 10 centimeters in diameter, will overnight cover an area half the size of a sheet of paper of letter size with a heavy layer of spores. Attempts to revive sporophores of this fungus 16 and 19 months old were unsuccessful.

Since these fungi fruit within mills (and at least three of them (*Lenzites sepiaria*, *L. trabea*, and *Lentinus lepideus*) are known to cast spores in abundance under mill conditions) it is probable that basidiospores play an important part in the dissemination of the fungi therein.

OBSERVATIONS ON THE DISSEMINATION OF THE BASIDIOSPORES OF TRAMETES SERIALIS.

The works of Falck (14) and Buller (8) have given us some information on the dissemination of the basidiospores of hymenomycetous fungi. Falck showed how the spores were dispersed uniformly within closed glass vessels, even to some height within narrow containers. His method of determining the dissemination was by collecting spore deposits upon shelves or ledges at various locations throughout the chamber. He showed with what ease currents of air, invisible and imperceptible, caused by temperature changes could transport the basidiospores. He found that insulated fruit bodies in insulated glass chambers have a higher temperature than the surrounding atmosphere and formulated a theory that the ability to produce this higher temperature was an adaptation serving to warm the layers of air beneath the pilei for the purpose of producing convection currents to disseminate the spores. He went farther and maintained that the thickened pilei of fleshy hymenomycetes were symbiotic adaptations providing food for maggots, whose respiration produces heat. Buller (8) demonstrated basidiospore dissemination by means of his beam-of-light method. His work was more comprehensive than Falck's, and while agreeing with Falck's general conclusions as to the ease of dissemination of these spores, he could not regard it as demonstrated that the heat of the pileus was of material help in disseminating spores in the open. He maintained that the convection currents naturally present at all times out of

doors were the important agents and that any convection currents formed by the heat of the pileus would be swamped by the natural currents under most conditions. Falck in a later work (16, pp. 226-227) demonstrated how the spores of *Merulius lacrymans* are scattered throughout buildings. He found that a fruit body off in a corner in a church spread spores throughout the edifice and that spores from fruit bodies in a cellar where the temperature was a little higher than that of the rest of the house were carried by air currents to various places in the house. He caught them on glass slides under a bed on a first floor and at places on the second floor. Even a closed door did not keep them out.

The writer had no opportunity to make extended observations on the dissemination of basidiospores, but several instances came to hand which corroborated in a small way the observations and conclusions of the above-mentioned authors. Certain observations presented here have to do with the fruiting of *Trametes serialis* in the fungus pit at Madison, Wis., already referred to. Two fruit bodies of this fungus appeared toward the last of January, 1919. One of them grew at the end of the under side of a horizontal timber. On entering the pit one day it was noticed that the transverse face and a part of the upper surface of the beam were powdered white with a deposit of the spores from the fruit body below (Pl. VI, fig. 1). Several similar deposits were noted in November, 1919, when several fruit bodies appeared, most of them on the under side or on the end of another beam. Here were cases in which the spores had been swept directly upward, as if carried by a strong draft from below. But just how there could be strong drafts it is difficult to understand. The pit is sunk 4 feet in the greenhouse floor, walled with concrete, and has a dirt floor and well-fitting covers. There is very little likelihood of air currents from outside. Glass slides placed beneath the sporophore gathered no spores, but slides placed at points throughout the pit, even at the top near the covers, collected enough spores to be located under the microscope.

In mills, however, the dissemination of spores is not dependent upon such imperceptible air movements, for considerable air currents are produced by rapidly moving machinery, sprays from humidifiers, and steam pipes poorly arranged. These currents become of great importance in distributing spores which may be cast into the air by fruit bodies upon the roof planks.

In the fungus pit on two occasions the opportunity presented itself for observing to what extent insects and other animals may under certain conditions disseminate wood-destroying fungi. There is little literature bearing upon this phase of the subject. One occasionally meets with references to the connection between wood

decays and insect burrows (cf. Spaulding, 56; 57, p. 115), but little is known as to how great an extent insects are responsible for carrying the spores of these fungi and starting infections. Hubbard (25, p. 251) reports that several bark insects have been found within the veil of *Cryptoporus volvatus* and suggests that such insects may carry the spores from fruit bodies into direct contact with the inner layers of bark of uninfected trees. One beetle (*Epuraea monogama* Crotch) he found (p. 253) always coated with a thick layer of the spores. Zeller (63, p. 124) has made similar observations in connection with the same fungus. The common occurrence of fungus gnats, mites, springtails, and slugs upon hymenia has been noted by several (Buller 8, pp. 19, 20, 23, 96).

The fruit bodies of *Trametes serialis* mentioned above appeared at a time following a thaw when a considerable quantity of water seeped into the fungus pit from the earth below, making a damp chamber of the whole pit. The dampness caused an abundance of spores to be cast. The beams bearing the sporophores were so situated that they were about 1 centimeter above a piece of plank. It was so moist in this space that water had collected on the plank under the sporophore and this water was full of basidiospores. With the advent of moist conditions within the pit also came sow bugs. They infested the woody material and were particularly abundant on and around the fruit bodies, even wallowing in the water full of basidiospores. A number of these animals, with small spiders and springtails associated with them, were collected and examined for spores and, of course, were found to bear great quantities of them. All animals collected on that particular beam had spores in varying quantities on their legs, antennæ, and setæ, and many of them, particularly the sow bugs, had a large number of spores upon their backs where they had fallen directly from the sporophore. A photomicrograph (Pl. VI, fig. 2) shows the immense number of spores on the appendages of sow bugs taken from the water beneath the fruit bodies. Sow bugs caught covered with spores as just described were transferred to flasks of sterilized wood blocks and incubated. The blocks became somewhat contaminated with *Penicillium*, as might be expected, although not heavily, but a hymenomycetous growth was noted in the flasks as well. After several months the blocks were removed and found to be decayed, showing that the dissemination of wood-destroying fungi by means of arthropodous animals is possible.

The point to be made in connection with the relation of sow bugs to the possible dissemination of basidiospores within buildings is that the fruiting of these fungi and the presence of the sow bugs are often tied up with moisture conditions. Certain fungi will fruit in moist places, especially near the earth and in small inclosed places

where damp chamber conditions prevail, and the sow bugs are present in the same environment, particularly where the light is weak. Such conditions are common in and around many structures.

Springtails also are of common occurrence in the fungus pit, and are found commonly on the moist decayed wood. It is possible that other insects which inhabit buildings, such as cockroaches and spiders, may take some part in disseminating basidiospores. In mills there is the possibility that insects may assist in the dissemination of these fungi as much as they assist in ordinary cases out of doors. Insects of several unidentified species feed upon the fruit bodies of both *Lentinus lepideus* and *Trametes serialis* to such an extent that sound specimens can be obtained only within a short time after formation. Insects coming in contact with fruiting surfaces can not fail to carry away spores, because of the nature of their appendages and the stickiness of the spores, as has been demonstrated.

MYCELIUM.

PREPARATION OF CULTURES.

The cultures of the five fungi used in the physiological studies were derived from single spores of the collections already noted. The method of obtaining the single-spore cultures was essentially that of Keitt (27). The basidiospores were allowed to swell, and before the germ tubes developed several were picked out and transferred to tubes of malt agar.

MACROSCOPIC APPEARANCE OF CULTURES GROWN AT ROOM TEMPERATURE.

In cultures of *Lenzites sepiaria* on malt agar no aerial growth is seen until a day or two after the submerged mycelium has appeared, and in some cases, especially in the dark, very little aerial mycelium is in evidence at all. The aerial growth (secondary mycelium) is very scant, at first white, and breaks up almost entirely into oidia, which give the surface of the culture a more or less damp-powdery appearance. In three weeks to a month this superficial growth may become avellaneous to wood brown.³ The writer has seldom seen anything but this secondary mycelium which breaks up into oidia, but occasionally a tertiary growth will appear over the oidia-forming mycelium, forming a more matted or patchy growth. At optimum temperature (30° to 34° C.) a 10-centimeter Petri dish is covered in about eight days. On wood the superficial growth is equally scant. The surfaces of the blocks become sparingly flecked with a white, coarse powdery growth, which is found

³ All colors referred to are those in Ridgway's "Color Standards and Color Nomenclature."

to consist for the most part of oidia, with a moderate amount of strand development on the surfaces and between the blocks. This growth on wood may turn wood brown in its later stages of development. No fruit-body formation has been observed in either the agar or wood cultures.

On malt agar the first growth of *Lenzites trabea* (the secondary mycelium) is white and has the same damp-powdery appearance, due to the pressure of oidia, as *L. sepiaria*. This secondary mycelium is much more abundant than that of *L. sepiaria*, however. In ten days or more this growth is followed by the tertiary mycelium, which begins in patches and later more or less entirely overgrows the secondary mycelium. It is thick, fluffy woolly, more or less bunched, in color pale yellow-orange to light ochraceous buff, and shows no sign of the powdery appearance, because it forms no oidia. It forms large yellow-orange masses of mycelium in the upper ends of agar slants and fruits quite abundantly after a month or more. On wood the first mycelium is white, and no oidia formation has been noted. The mycelial growth is more abundant than that of *Lenzites sepiaria*, more bunched and patchy, and becomes colored as noted upon malt agar.

Trametes serialis on malt agar makes a white cottony growth, slightly patchy at times, and occasionally may be more fluffy and thick near the periphery of the culture. In later stages there is a tendency toward a snuff-brown color. In tubes the superficial mycelium forms a fluffy white mass, which grows up the walls. The upper end of the slant becomes sepia or auburn with age and occasionally develops a thick brown mass of mycelium which forms pores. On wood this fungus at first makes a thick growth over the individual blocks with some strand formation and then continues to form an abundance of white mycelium which fills the interstices between the blocks, finally covering the wood with a thick snow-white mass in three or four months. This mycelial growth may become more or less suffused with a brownish tint and may form a brown exudate in places. When the blocks are removed from the flasks after six months or more, they are covered with a thick white mass having a consistency of cream cheese. Abortive irpiciform fruit bodies, having plates instead of normal pores, are formed after six months in these block culture flasks and occasionally resupinate poroid forms develop upon the slanting sides of the flasks, connected with the mycelial mass by thick strands.

Single-spore cultures of *Fomes roseus* form a white cottony growth on malt agar, thicker and more compact than those of *Trametes serialis*, having the appearance of washed cotton flannel. They are white in color when fresh, becoming avellaneous or snuff

brown with age in patches and at the upper ends of slants. The writer's single-spore cultures from the annual form of the fungus upon coniferous hosts have only rarely developed any pink color, and then only a pale pinkish cast after 18 to 20 months of transferring. Single-spore cultures from the annual form upon *Prunus* sp. have developed colors from pink to Mars brown in patches or streaks. Tissue cultures from the annual form upon spruce have taken on only a pale-pink color, but similar cultures from the perennial form have developed a thick mat of mycelium old rose to Mars brown. The same cultures, with the exception of the single-spore cultures used in these experiments, have varied from transfer to transfer both in color and character of growth. This growth may be described as above, a thick mat, as in the tissue culture of the perennial form, or varying, thick, irregular growths, as found in other cultures. Layers of pores have been formed in the cultures derived from sporophores, but not as yet in the single-spore cultures. The culture of *Fomes roseus* used by the writer in this work is a relatively slow grower, covering a 10-centimeter Petri dish in 12 days at its optimum temperature.

On wood the slowly growing mycelium of the culture used eventually completely covers the blocks, but the growth is very thin, not at all fluffy or abundant, and the interstices between the blocks are not filled as they are by *Trametes serialis* or *Lentinus lepideus*. There is no great mass of superficial mycelium formed. The growth upon the blocks has the same washed-flannel appearance as have the agar-plate cultures, has abundant strand formation, and may become chestnut to argus brown in places in nine months or more.

Young cultures of *Lentinus lepideus* on agar are light cottony or felty, with more or less tendency to the formation of thin and thick zones of aerial mycelium. The inoculum turns snuff brown in two weeks, and the rest of the aerial growth turns buckthorn brown to cinnamon brown as it grows older, perhaps only in patches. In one month the culture may develop numerous umbonate or tubercular cushions of mycelium, which vary from white to Prout's brown, exude droplets of a dark color, and have a distinct aromatic odor. They are apparently either primordia of sporophores or abortive fruit bodies. No well-formed sporophores have developed in the writer's plate cultures. Strand formation is quite pronounced in four to six weeks. In tubes the cultures are much the same as the plate cultures. In the wood cultures in flasks the mycelial growth is abundant, covering the blocks, at first white and later becoming buckthorn brown or bister in patches, forming abortive fruit bodies in six to nine months. Clusters of long thin crystals are formed

quite abundantly throughout the flasks. The mycelium of *Lentinus lepideus* covers the individual blocks with a bunchy, uneven growth, while that of *Trametes serialis* forms a thick, even growth over the whole mass of blocks. Yet the mycelium of the former fungus binds the blocks quite solidly together, so that it takes some little effort either to remove individual blocks from the flask or to loosen the mass for emptying the flask, while the more pronounced mycelial growth of *Trametes serialis* does not have such a binding effect. The aromatic odor mentioned is much more pronounced in the flask block cultures; the other four fungi here studied do not produce such an odor.

MICROSCOPIC CHARACTERS OF THE MYCELIA ON MALT AGAR.

Lenzites sepiaria:

Secondary mycelium—

Submerged.

Colorless, avellaneous in mass; 1.5 to 4.6 μ^4 , most 2.5 to 3.2 μ ; septa fairly abundant; branching not abundant; clamps not observed; chlamydospores and oidia found occasionally on submerged mycelium, the latter chiefly in agar drop cultures.

Aerial.

Colorless; chiefly short, branched hyphæ which break up more or less completely to oidia; size same as submerged; septa fairly abundant; no clamps observed. Oidia colorless, mostly ellipsoid-oblong, occasionally ellipsoid, ovoid, globose, pyriform, or clavate, occasionally septate; terminal oidia usually clavate; 2.5 to 3 $\mu \times$ 4 to 35 μ ; helicoid hyphæ present, but not abundant.

Tertiary mycelium (aerial)—

Seldom noted in the writer's single-spore cultures. In cultures from sporophores, more abundant; long, stiff, hairlike, sparingly branched, septa not abundant, clamps at septa.

Lenzites trabea:

Secondary mycelium—

Submerged.

Colorless; 1.5 to 3 μ ; irregular; branching, clamps, and septa abundant; chlamydospores much less abundant than the oidia, thin or thick walled, terminal or intercalary, ovoid to globoid, 6 to 8 $\times$ 8 to 18 μ .

Aerial.

Colorless; 1.5 to 3 μ ; branching common, usually at right angles; clamps and septa fairly abundant; oidia abundant, mostly cylindrical to ellipsoid-oblong, terminal ones ovoid to pyriform and clavate or even globoid, 2 to 8 $\times$ 6 to 24 μ , mostly about 5 $\times$ 10 μ .

Tertiary mycelium (aerial)—

Colorless, slightly yellowish in mass; long, straight, and stiff; branching and septa not abundant; clamps fairly abundant; no oidia or chlamydospores observed.

⁴ The figures in these descriptions refer to the range of measurements observed during ordinary examination.

Trametes serialis:

Secondary mycelium—

Submerged.

Colorless; 3.3 to 6.3 μ ; septa relatively few, far apart in some hyphæ, close together in others; clamps very few and small; branching more frequent than in aerial vegetative mycelium, may begin as close to growing tip as 150 μ , but usually farther back; contents of young hyphæ homogeneous, with occasional angular crystals; chlamydospores fairly common, varying more or less with age of culture, very abundant in old cultures; colorless, ellipsoid, fairly thick walled, 4.5 to 10 $\times$ 7 to 21 μ , occurring intercalarily.

Aerial.

Vegetative mycelium: Colorless; 1.5 to 3.6 μ ; septa and clamps fewer than in fruiting mycelium, but fairly abundant; branching irregular, not abundant, not necessarily at right angles, with forking common; hyphæ straight for the most part, contents homogeneous; anastomosing occasional; chlamydospores few, similar to those on submerged mycelium.

Tertiary mycelium (aerial)—

Fruiting mycelium: Colorless; 4 to 6.6 μ ; of unequal thickness, much of it with contents gone and only walls left; abundant protuberances, round or bluntly pointed; branching common, usually at clamps; septa and clamps abundant; anastomosing common; chlamydospores as above.

Fomes roseus:

Secondary mycelium—

Submerged.

Colorless; 0.8 to 3.6 μ , occasionally 4.6 μ , with much small mycelium; septa and branching not abundant; clamps not observed; branching begins near tip of young growing hyphæ; no secondary spores observed.

Aerial.

Colorless; smallest hyphæ 0.8 to 1 μ , more commonly 2 to 3.1 μ , occasionally 3.8 to 4.7 μ ; septa not abundant; branching not abundant; may or may not be at septa; clamps few; anastomosing of smaller hyphæ occasional; no secondary spores observed.

Tertiary mycelium (aerial)—

Colorless, pinkish in mass; 2 to 3 μ ; no branches or clamps; stiff, hairlike.

Lentinus lepideus:

Secondary mycelium—

Submerged.

Colorless; 3.5 to 4 μ ; septa abundant, hyphæ constricted at septa; branching may begin near tip of growing hyphæ, not necessarily at septa or clamps; clamps fairly abundant; anastomosing occasional at clamps; chlamydospores colorless, thick-walled, usually ellipsoid, occurring intercalarily or terminally on short lateral branches; 8 to 14 $\times$ 10 to 20 μ .

Aerial.

Colorless; 2 to 3 μ ; branching common, also septa; clamps few; chlamydospores colorless, 8 to 14 $\times$ 10 to 20 μ , usually ellipsoid, occasionally ovoid or ellipsoid-oblong, usually terminal, but occasionally intercalary, commonly empty, commonly showing secondary walls due to contraction of contents.

Tertiary mycelium (aerial)—

Colorless as a rule, with occasional hazel hyphæ, may be slightly colored in mass; 2.2 to 5.6 μ ; long, stiff, hairlike; chlamydospores as described in the secondary mycelium; thick walled; irregular hyphæ common.

DIFFERENTIATION OF THE CULTURES UPON AGAR.

Agar plate cultures of the five fungi under consideration in these studies are readily distinguished macroscopically. *Lenzites sepiaria* is readily distinguishable because of its scant superficial mycelium, even occasional lack of it, and the powdery appearance due to the oidia. *Lenzites trabea* can readily be distinguished as to its secondary mycelium by the presence of chlamydospores along with the oidia, inasmuch as the chlamydospores of *L. sepiaria* are very scarce and seldom found on malt agar. Its tertiary mycelium is dense, matted, and patchy and in color yellow-orange to ochraceous buff. It forms large fluffy masses at the upper ends of malt agar slants.

Of the remaining fungi here studied, *Fomes roseus* may show only a white secondary mycelium, which will be either uniform or very irregular in thickness, or there will be formed a tertiary mycelium from pale-pink tints to old rose and Mars brown in color. It is also a more slowly growing organism at its optimum temperature than *Lenzites sepiaria*, *L. trabea*, or *Trametes serialis*. *Lentinus lepideus* grows at about the same rate as *Fomes roseus*, taking 12 days at optimum temperature to cover a 10-centimeter Petri dish. *Trametes serialis* is a rapidly growing fungus, covering the dish in 7 days at optimum temperature. *Lentinus lepideus* soon takes on a brownish cast, forms umbonate abortive fruiting bodies in the Petri dishes, and usually has a distinct aromatic odor.

A conspectus of diagnostic characters of agar cultures of the five fungi is presented in key form. The characters are based on cultures at least 3 weeks old and grown at temperatures from 20° to 30° C.

I. Oidia present.

A. Growth usually white, scant and powdery, but occasionally more abundant, and shades of brown or sepia in color, especially fruit-body cultures; true chlamydospores scarce, but many spherical or pyriform oidia may be present.....*Lenzites sepiaria*.

B. Early growth (secondary mycelium) scant and powdery, but usually containing many true chlamydospores; later growth (tertiary mycelium) abundant, containing no secondary spores, pale yellow-orange to light ochraceous buff in color; abortive poroid or irpiciform fruit bodies formed.....*Lenzites trabea*.

II. No secondary spores present; tissue cultures soon becoming pink, old rose, or shades of brown; basidiospore cultures remaining white indefinitely or becoming pink with age.....*Fomes roseus*.

III. Chlamydospores present, but no oidia.

- A. Mycelium tough, brownish in old agar cultures; with abortive fruit bodies, especially in plate cultures; covers 10-cm. Petri dish in 12 days at 28° C.; aerial chlamydospores often showing contraction of the protoplasm and formation of thick secondary walls; usually having a strong aromatic odor.....*Lentinus lepideus*.
- B. Mycelium white; no abortive fruit bodies; covers 10-cm. Petri dish in seven days at 28° C.; chlamydospores more abundant in submerged mycelium.....*Trametes serialis*.

EFFECT OF TEMPERATURE ON THE GROWTH OF THE MYCELIUM.

The tests on the effect of temperature upon the growth of the mycelium were made on malt agar in 10-centimeter Petri dishes. The

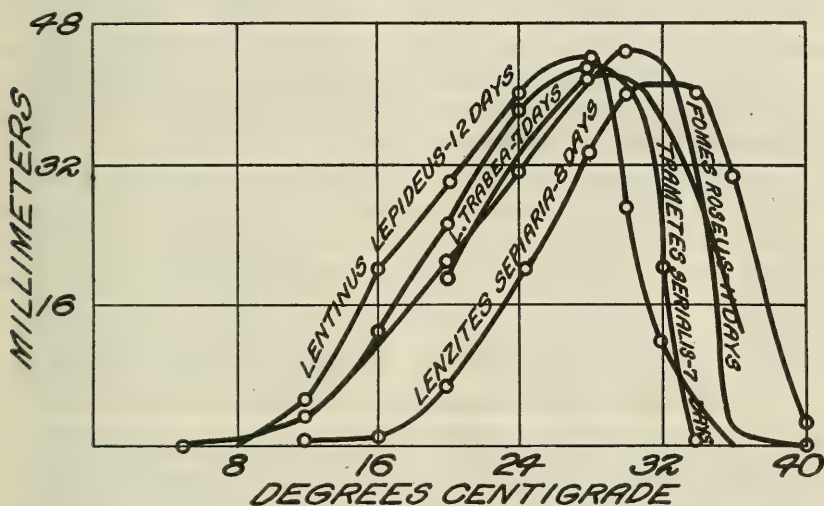


FIG. 2.—Effect of temperature upon the growth of the mycelium upon malt agar (shown in millimeters of radial growth from the inoculum).

inoculum consisted of a block of agar 8 to 10 millimeters square, with its mycelium, cut from the young growth of a previously prepared Petri dish culture. This transfer was deposited upon the surface of the agar in the center of the dish. Growth was measured in millimeters radially from the edge of the inoculum. The results of the tests upon the five fungi are given in figure 2 and in Plate VII. For *Lenzites sepiaria* the optimum lies at 30° to 34° C. (85° to 93° F.). At 3° and 8° C. (37° and 46° F.), there was no noticeable growth in 8 days, and after a month there was no growth at 3° C. and only a millimeter or two at 8° C. At 40° C. (104° F.) results varied. Occasionally there was no noticeable growth until after 18 days, when it varied from 1 to 3 millimeters; at other times 1 to 5 millimeters was evident in 8 days. No growth took place at 44° C. (111° F.). Falek (15, pp. 127-129) obtained somewhat different results for this fungus.

He found the optimum to be 35° C. (95° F.), the minimum 5° C. (39° F.), and the maximum point 44° C. (111° F.).

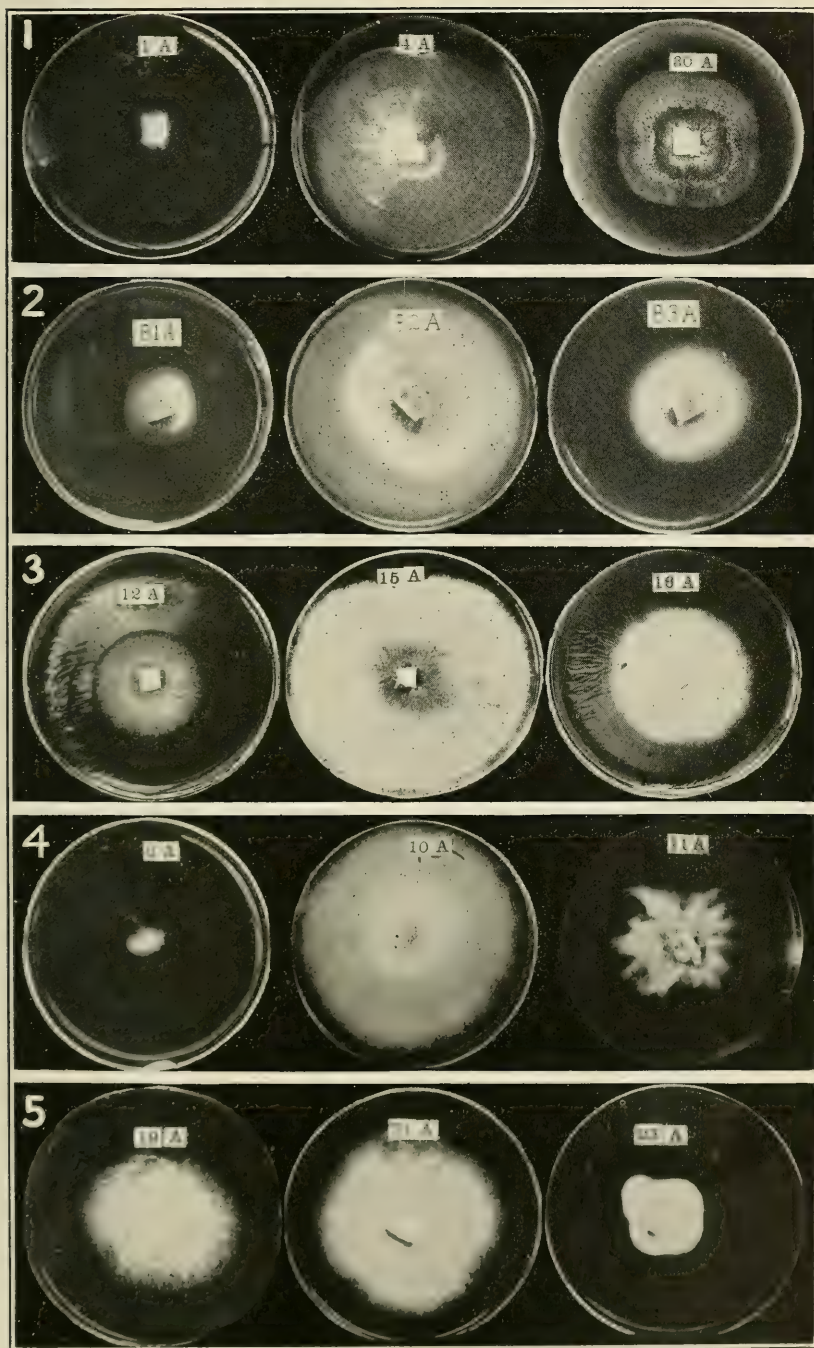
Lenzites trabea makes a moderately rapid growth, covering the dish in seven or eight days. It grows fastest at 28° C., although nearly as rapidly at 30° C. It grows only very slightly at 40° C. (104° F.).

Trametes serialis grows at about the same rate as *Lenzites sepiaria*, covering the dish in 7 days. The optimum for *T. serialis* is at 28° C. (82° F.). No growth occurred at 34° C. (93° F.), and at 3° C. (37° F.) none was noticed until after 39 days, when it was seen to be alive and barely growing. *Fomes roseus* is a more slowly growing organism, taking 11 days at the optimum temperature (30° C.) to cover the 10-cm. Petri dish used. At 3° C. there were signs of growth in 12 days, but very little at 36° C. (97° F.) and none at 40° C. (104° F.). Upon microscopic examination it was seen that at 40° C. hyphæ had started to grow, but had died. *Lentinus lepideus* also grows at a moderate rate; in most of the tests the dish was not quite covered in 12 days. Its optimum was found to be 28° C. (82° F.). Its range of growth was narrower than that of the other three fungi. No growth was noted at 8° C. (46° F.) in 12 days, and at 36° C. (97° F.) there was less than 1 mm. in the same period. No growth was visible at 40° C. (104° F.).

SECONDARY SPORES.

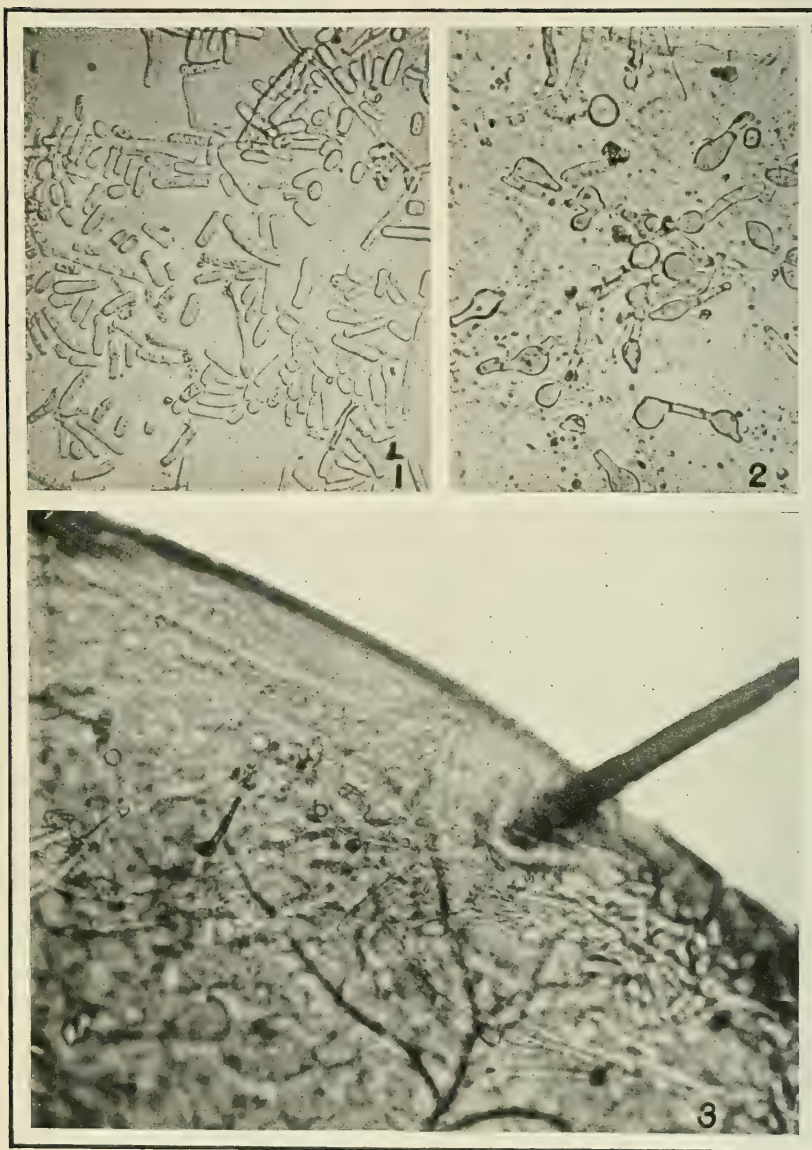
INTRAMURAL DISSEMINATION OF FUNGI CAUSING DECAY.

One of the most interesting problems in connection with the decay of building timbers is that of the intramural dissemination of the causal organisms. Abundant proof is at hand to attest the activity of the mycelium in spreading decay throughout a building by direct growth from one timber to another. Falck (16, pp. 245-247) has shown how the mycelium of the dry-rot fungus (*Merulius lacrymans*) can grow through structures and even for some feet over brick and stone masonry from one piece of timber to another. Wehmer (61) has shown the same for cultures of *Coniophora cerebella*. The dissemination of *M. lacrymans* by means of rhizomorphs is also well known (cf. Falck and others). The dissemination by means of basidiosporic fructification has already been mentioned. While conditions in textile and paper mills may occasionally favor the formation of fruit bodies, of certain species at least, conditions also may prevail which will likewise prevent the formation of such fruit bodies. It has been shown that *Trametes serialis* can fruit and cast spores in the dark. On the other hand, *Lenzites sepiaria* can not form normal fruit bodies in the absence of light (see Falck, 15, for reference and discussion), and the same is true of *Lentinus lepideus*.



EFFECT OF TEMPERATURE UPON THE GROWTH OF THE MYCELIUM.

FIG. 1.—Growth of *Lenzites sepiaria* for 8 days: 1A, at 18° C.; 4A, at 32° C.; 30A, at 36° C. FIG. 2.—Growth of *Lenzites trabea* for 7 days: 81A, at 16° C.; 82A, at 28° C.; 83A, at 36° C. FIG. 3.—Growth of *Trametes serialis* for 8 days: 12A, 12° C.; 15A, at 28° C.; 16A, at 32° C. FIG. 4.—Growth of *Fomes roseus* for 11 days: 6A, at 12° C.; 10A, at 30° C.; 11A, at 34° C. FIG. 5.—Growth of *Lentinus lepideus* for 12 days: 19A, at 24° C.; 21A, at 28° C.; 23A, at 32° C.



FUNGI STUDIES OF IMPORTANCE IN THE DECAY OF BUILDING TIMBERS.

($\times 523$.)

FIG. 1.—Oidia of *Lenzites sepiaria* from malt-agar culture. FIG. 2.—Stages in formation of chlamydospores of *Trametes serialis* on secondary mycelium in malt agar, with a few thin-walled chlamydospores. FIG. 3.—Oidia and mycelium of *Lenzites sepiaria* upon fibia of cockroach allowed to roam over wood block culture over night.

(Buller, 6, p. 428; 7, p. 6; and Jaczewski, 26, p. 407). Under these circumstances the question naturally arises whether or not secondary spores might be produced by some of these organisms and thus account for the rapidity with which decay spreads in certain types of buildings. In certain places in mills, as basements and between floors, for example, light may be insufficient for fruit-body formation, yet this lack of light and the abundance of moisture would be highly favorable for the growth of superficial mycelium, and hence, perhaps, for the production of secondary spores. With these possibilities in mind, considerable attention was paid to the observation and study of the secondary spores formed by the five organisms in question.

REVIEW OF THE LITERATURE OF SECONDARY SPORE FORMATION.

GENERAL SUMMARY.

The subject matter relative to secondary spores has been well summarized by Lyman (31). His conclusions (p. 202) were: That a majority of the hymenomycetes have no secondary spores; that oidia are common among the Polyporaceæ and Agaricaceæ and are confined to these two families; that chlamydospores occasionally occur in connection with the basidial fructification and are quite widely distributed on the mycelium of all families; and that conidia and other highly specialized methods of reproductions (bulbils, etc.) are rare and occur more frequently in the Thelephoraceæ than in the higher families. Since Lyman's paper, only scattering references to secondary spores have appeared. Of these only a few are of interest here. Marryat (32) found chlamydospores of *Pleurotus subpalmatus* in the vessels of wood-block cultures. Rumbold (49) not only reported secondary spores for the first time in a few species of wood-destroying fungi, but studied their formation, germination, and subsequent development. Falck produced two comprehensive volumes, one in 1909 on the decay produced by species of *Lenzites* (15) and the other in 1912 on the decays caused by species of *Merulius* (16). In these he takes up in a thorough way the occurrence, the methods and conditions of formation, and the germination under various conditions of the oidia in the species considered. In the later work (16, p. 132-133) he makes some general remarks upon these oidia. He considers them of two kinds—a transition, or tiding over, form (*Übergangsfruchtform*), as found in *Merulius*, and a true secondary form (*Nebenfruchtform*), as found in *Coniophora*. The former he says are not formed under normal conditions (*natürlichen Verhältnissen*) but only when conditions become unfavorable for growth of the fungus. Their viability is reduced and they are capable of being disseminated only to a slight degree. The latter are found under

normal conditions of growth, and their formation is independent of environmental conditions. They germinate immediately and normally, are formed in loose dustlike masses, and are easily removed. The former he considers a facultative transition form and the latter a true propagative form.

Hotson in two papers (22 and 23) extended and summarized our knowledge of bulbils and similar propagative forms, and added the finding of bulbils in a few basidiomycetes. Learn (28), in his cultures of *Pleurotus ostreatus*, noted the formation of new mycelial growths at the base of wood-block cultures below blocks bearing oidia. This suggested the shedding of these oidia from above. Weir (62) noted a *Ptychogaster* form in connection with *Trametes suaveolens* growing naturally, and he remarks that in the damp woods of Idaho there are many abnormal polyporoid forms, some of them conidial. In *Fomes officinalis*, Faull (18) found chlamydospores not only in cultures but also in the crust of the sporophores. The writer has found the chlamydospores of this fungus on rotting wood in nature (55). Hiley (20) reviewed the status of the conidia of *Fomes annosus*.

REFERENCES TO THE OCCURRENCE OF SECONDARY SPORES IN NATURE.

The references to secondary spores occurring in nature are quite numerous. Perhaps the least understood of the fungi producing secondary spores are the *Ptychogasters*, which are considered abnormal conidial or chlamydospore fructifications of the polypores. Observations on the *Ptychogasters* occur chiefly in the older literature, and reference may be had to Boudier (3 and 4), De Seynes (50, 51, 52, 53, 54), Richon (48), Ludwig (30), Patouillard (42 and 43), Brefeld (5), and Weir (62). Then there are the spores reported as conidia, called "wet-weather spores" by Lyman (31, p. 135), who said that until these spores had been more thoroughly investigated their nature must be regarded "as uncertain and their occasional production as of doubtful importance to the fungus." (Cf. Patouillard, 41, 44, 46; Eichelbaum, 11; and Massee, 33.) Of the references to secondary spores in nature the status of which is more certain, we might mention the following: Chlamydospores on the hairs of the stipe of *Pleurotus ostreatus* (Patouillard, 39) and in the hymenium (Matruchot, 34); chlamydospores in groups or singly in *Trametes rubescens* (*Daedalea confragosa*) (Patouillard, 40); chlamydospores in fruit bodies of *Polyporus sulfureus* (De Seynes, 50, 51); conidia (chlamydospores according to Lyman, 31, p. 136) in the hymenium of *Hydnum coralloides* (De Seynes, 53); terminal chlamydospores in *Fistulina hepatica* (De Seynes, 50); chlamydospores on and in the pileus of *Nyctalis asterophora* and *N. parasitica* and conidia of *Fomes*

annosus found by Olsen (Brefeld 5, p. 177); chlamydospores between the margin and the poriferous zone in *Polyporus bambusinus* (Patouillard, 45); conidia (chlamydospores according to Lyman) in *Stereum disciforme* and all over the hymenium of *Aleurodiscus oakesii* and *A. amorphus* (Patouillard, 46); conidia on racemose organs in the hymenium before formation of basidiospores in species of *Aleurodiscus* (Burt, 9, p. 198); viable chlamydospores on branches of the stipe of *Collybia racemosa* (Stefan, 59); helicoid conidia on hairs arising from the young veil and from the margin of the developing pileus of *Lentodium squamulosum* (*Lentinus tigrinus* Fr.) (Lyman, 31; p. 186) and on the mycelium overgrowing the gills of the same fungus (Murrill, 38, p. 296). Further, Cool (10) found oidia coming from the pileus during basidiospore casting of *Collybia velutipes* (p. 9) and chlamydospores along with the basidiospores of *Sphaerobolus stellatus* (p. 21). She also reports that she found a great many more oidia than basidiospores in the hymenial layer of *Collybia velutipes* and wart-shaped heaps of oidia on the dried fruit bodies of this fungus. Long and Harsch (29) report the chlamydospores of *Lentinus lepideus*. We have already mentioned Weir (62) and the observation of Faull (18) and the writer (55) on the chlamydospores of *Fomes officinalis*.

REFERENCES TO THE IMPORTANCE OF SECONDARY SPORES IN THE DISSEMINATION OF FUNGI.

There are a few references to the importance of secondary spores in the dissemination of fungi. Eidam (12, p. 245) concluded that there was no natural secondary reproduction in *Cyathus striatus* and that the oidia were an abnormal appearance, although they might tide over unfavorable conditions. In speaking of the failure of Hartig's isolation trench in checking the spread of *Fomes annosus*, Brefeld (5, pp. 153 and 179-185) suggested as the reason that conidia were formed by this fungus that they infected the cut roots and thus produced more disease than normally occurred. Brefeld never found conidia growing naturally, although he reports such a finding by Olsen (5, p. 177), but he obtained them in the laboratory on mycelium collected in the woods (5, p. 153). Hiley, in reviewing the status of the conidia of this fungus in relation to decay of the larch, reports (20) the production of conidia in wood cultures and upon sterilized soil. He believes it probable that the mycelium of *Fomes annosus* "may grow on forest soil and bear conidia" (p. 115) and that one of the means of infection of the host is by these conidia (pp. 115, 121, 123). Tubenff (60, p. 103) had nothing concrete to offer on the propagation of *Merulius* by secondary spore forms, but emphasized the theoretical importance of such. He pointed out that

the basidiospores of the dry-rot fungus are difficult to germinate and may have low germinability in nature. He further states that the chlamydospores (asserted to be oidia by Falck) if found outside artificial cultures would probably contribute to the spread of the fungus. Falck (16, p. 132), on the other hand, maintained that the oidia of *Merulius* were not true propagation organs. The same writer in 1902 (13, p. 319) remarked that insects must spread the oidia of *Hypholoma* and *Pholiota*, which are formed in abundance on firm substrates. He believed that the formation of oidia on blocks infected with *Collybia velutipes* placed in moist moss illustrated the importance of these spores in nature. These oidia were formed in colonies in the air, undoubtedly for insect dissemination, he avers, but he doubts whether they could be detached by the wind. Falck (15, p. 144) also maintained that the tertiary oidia of *Lenzites sepiaria* "doubtless play an important part as organs of propagation, inasmuch as the spores might easily be carried away by animals in creases of their bodies, etc. A somewhat rough shaking loosens single end-spores from one another, and these can easily be collected on slides held beneath."

Münch (37, p. 577), however, believes that oidia do not possess in nature the great significance for the spread of the fungus which Falck claimed for them. He observes that the conditions of oidia formation are not clear, that their formation in nature is not possible in cases that have come to his attention, because of the inability of the fungus to get to the air, and that direct observations of oidia in nature are lacking. He asserts that this form of reproduction is merely a makeshift at best and not a normal reproductive form. Faull (18, p. 201), as mentioned above, found chlamydospores in the crust of sporophores of *Fomes officinalis* and expressed the belief that they are a means of reproducing the fungus, although the viability of these chlamydospores appearing naturally was not tested. The finding of chlamydospores of this fungus in nature by the writer (55) has suggested their importance in the spread of the fungus.

OCCURRENCE OF SECONDARY SPORES IN CULTURES OF THE FUNGI STUDIED.

Of the five fungi used by the writer in these studies, secondary spores have been found in four. Oidia have been previously reported in cultures of *Lenzites sepiaria* by Rumbold (49) and Falck (15) and chlamydospores also by Falck. Long and Harsch (29) reported the occurrence of chlamydospores in cultures of *Lentinus lepideus*. As far as the writer knows, the chlamydospores formed by *Trametes serialis* have not been reported, although Mez (35, p. 116) mentioned a brown corky *Ptychogaster* form of this species

with deep pores. Brefeld (5, p. 106) reported in *Trametes serialis* aerial oidia which would germinate and made the observation that their formation occurred only on young mycelium, never on old. The writer's cultures have developed no oidia. The oidia and chlamydospores in *Lenzites trabea* have not been reported. No secondary form has been noted in *Fomes roseus*. Chlamydospores have been seen in cultures of *Lenzites sepiaria*, but have been scarce. They could not have appeared abundantly in Falck's cultures, for he little more than mentions them. All his references to secondary spore production by this fungus are to the oidia, and he describes no physiological tests upon the chlamydospores.

Oidia have appeared to a limited extent in the submerged mycelium of *Lenzites sepiaria*, chiefly in the hanging agar drop cultures (Pl. III, figs. 3 and 10), while the aerial oidia have been quite abundant with some variations (Pl. III, figs. 4-7; and Pl. VIII, fig. 1). Oidia have been quite abundant also in wood cultures. What little aerial mycelium forms on either wood or agar breaks up almost entirely to oidia. The occurrence and method of formation has been described sufficiently by Falck (15, pp. 139-140). He describes primary, secondary, and tertiary oidia according as they are formed on primary, secondary, or tertiary mycelium. The secondary oidia are never formed on the natural substrate of the fungus, according to him, but abundantly on agar, while the whole superficial growth of tertiary mycelium on agar or wood forms oidia in moist air. Chlamydospores and chlamydosporelike bodies (Pl. III, figs. 12 and 13) are found in small numbers upon the submerged mycelium. The secondary mycelium of *Lenzites trabea* develops oidia in abundance (Pl. IV, fig. 2) and chlamydospores in fair numbers (Pl. IV, figs. 3 and 4). The oidia are formed on the superficial mycelium and the chlamydospores on the submerged so far as can be determined. Some of the latter spores are thin walled and appear much like rounded oidia. Many of the chlamydospores show the contraction of the protoplasm and the abandoned cross walls (Pl. IV, fig. 4), as in the chlamydospores of *Trametes serialis* and *Lentinus lepideus*.

The chlamydospores of *Trametes serialis* (Pl. IV, figs. 6, 7, 8; and Pl. VIII, fig. 2) have appeared regularly in the writer's cultures and fairly abundantly. They are found for the most part on the submerged mycelium, although sparingly in the aerial fruiting mycelium at the upper end of older agar slant cultures, where abortive fruit bodies are formed. The method of development is that described by Lyman for other basidiomycetes (31, p. 150, pls. 19, 21, and 22) and illustrated in Plate IV, figure 6, and Plate VIII, figure 2.

The chlamydospores of *Lentinus lepideus* (Pl. V, figs. 4 and 5) have never been found abundantly. They occur in a living condition

on the submerged mycelium after about 10 days, but are empty and dead in 2 months.

The secondary spores of the four species considered here are formed on all the nutrient media tried, although in varying quantities, but *Lenzites sepiaria* is the only species so far known to form them on wood. Temperature has no appreciable effect on the formation of these spores on malt agar. Early in the work it seemed as if light favored the formation of oidia by *Lenzites sepiaria* and that darkness prevented it, but a variety of tests, variously checked, failed to give absolutely consistent results. Yet it was found that cultures started in the light nearly always formed oidia, while those in the dark seldom did.

GERMINATION STUDIES OF THE SECONDARY SPORES.

The oidia of *Lenzites sepiaria* germinate readily and to practically 100 per cent on agar. The cylindrical oidia as a rule simply lengthen out at either end or both ends with no swelling, so that no sign of the original oidium is left (Pl. III, fig. 11). Germination may begin, however, with a swelling of the oidium, at one end or in the middle, and the germ tube may then arise from either the swollen or unswollen ends (Pl. III, fig. 9). The club-shaped oidia which are found occasionally may send out one or more tubes from either the swollen or unswollen ends. In water the tubes are attenuated. The chlamydospores of *Lenzites sepiaria* germinate normally (Pl. III, fig. 10). The oidia and chlamydospores of *Lenzites trabea* germinate in a manner similar to those of *L. sepiaria*. The chlamydospores of *Trametes serialis* (Pl. IV, fig. 9), and *Lentinus lepideus* send out tubes from either end of the ellipsoid spores, although usually from only one end.

Germination tests were carried out upon the oidia of *Lenzites sepiaria* and *Lenzites trabea* and the chlamydospores of *Trametes serialis*. The chlamydospores of *L. sepiaria* and *L. trabea* were not readily obtainable in sufficient quantities and were hard to separate from the oidia. The chlamydospores of *Lentinus lepideus* could not be obtained in a condition which would allow of their manipulation. The chlamydospores of all four fungi occur chiefly, if not entirely, on the submerged mycelium in the agar. Those of *Trametes serialis* could be obtained in sufficient numbers by scraping the submerged mycelium, with as little agar as possible, from the surface of the culture, then macerating this material between two thick glass slides which had been previously flamed and finally removing this macerated mixture to sterile water blanks. The chlamydospores were separated from the mycelium by this process and the mycelium sufficiently injured so that it did not interfere with germination

tests. This method was not entirely satisfactory, but was the best that could be used in view of the lack of chlamydospores in quantity on the aerial mycelium. This method would not produce results with the chlamydospores of *Lentinus lepideus*, however, because they could not be separated from the mycelium, which appeared to be rather tough. The spores were not abundant in the first place, and germination tests on the few obtained were unsatisfactory, because the mycelium in the macerated mass overgrew the germinating chlamydospores.

All of the secondary spores germinate readily on various agars or in tap water. In distilled water numerous tests have shown that the oidia germinate sparingly (usually less than 1 per cent and produce only a small amount of attenuated mycelium. The chlamydospores could not fairly be tested in distilled water, on account of the difficulty in obtaining the spores free from mycelium, agar, etc., as explained above. On red spruce the secondary spores germinate normally as to time and manner, although forming attenuated mycelium.

TEMPERATURE.

The curves shown in figure 3 represent the effect of temperature upon the germination of oidia of *Lenzites sepiaria* and *L. trabea* and the chlamydospores of *Trametes serialis*. It will be noted that most of the oidia of both species germinated even at the extreme temperatures. At 5° C. (22° F.) in 5 days only 35 per cent of the oidia of *L. sepiaria* had germinated, 75 per cent in 11 days, and 80 per cent in 14 days. At 44° C. (111° F.) the oidia of both *L. sepiaria* and *L. trabea* germinated to practically 100 per cent in 20 hours. The oidia of *L. sepiaria* germinated most rapidly at 36° C. (97° F.) and that of *L. trabea* at 32° C. (89° F.).

About 75 per cent of the chlamydospores of *Trametes serialis* germinated between 20° and 32° C. (68° and 89° F.). In three weeks 35 per cent germinated at 50° C., but none germinated at 36° in repeated tests. The rate of development was optimum around 28° and 32° C. (82° and 89° F.).

A comparison of the cardinal temperatures for rate of germination of the basidiospores and secondary spores with growth of the mycelium of the five fungi studied shows that they correspond quite closely. The optimum for basidiospores extends over a little wider range of temperature than for the secondary spores or mycelium. The maximum temperature for the germination of the basidiospores is somewhat higher, by a few degrees, than for the growth of the mycelium of all five fungi. The oidia of *Lenzites sepiaria* and *L.*

trabea showed little or no retarding effect in percentage of germination at 44° C.

A single test upon the effect of cold on the oidia of *Lenzites sepiaria* and chlamydospores of *Trametes serialis* was made. Slides

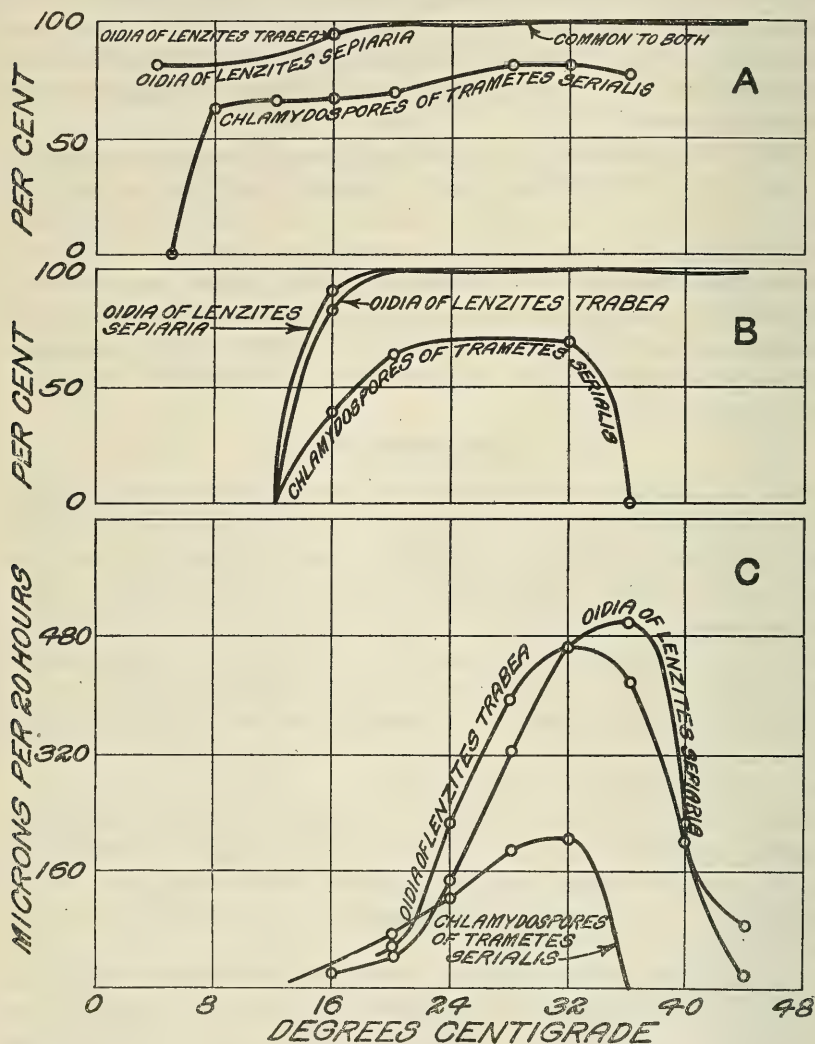


FIG. 3.—Effect of temperature upon the germination of the oidia of *Lenzites sepiaria* and *L. trabea* and of the chlamydospores of *Trametes serialis*. A, Effect of temperature upon the percentage of germination, showing the maximum percentage obtained, regardless of the time element; B, percentage of germination in 20 hours; C, rate of growth of the thalli in 20 hours (shown in microns).

were left out of doors over night when the temperature varied from -19° C. to -23° C. (-3° to -10° F.). The next morning germination tests were made, and it was found that the oidia had not been

affected, practically 100 per cent germination resulting, while the chlamydospores did not germinate at all.

LIGHT.

The diffused light from an east window during the winter apparently had little effect on the germination of the secondary spores. The oidia of *Lenzites sepiaria* and *L. trabea* germinated almost perfectly in diffused light or in the dark, although the development was somewhat more rapid in the dark. The same is true of chlamydospores of *Trametes serialis*, except that the percentage was between 50 and 60 rather than around 100.

In the month of May, 10 hours of direct sunlight acting upon the secondary spores upon agar not only inhibited germination during that period but prevented subsequent germination altogether. Experiments upon the killing effect of direct sunlight upon these spores when resting could not be carried out, inasmuch as it was impossible to separate the effects of drying from the effects of sunlight, because, as will be shown, drying materially reduces the percentage of germination.

DRYING.

There have been a few reports of the resistance of secondary spores to drying. De Seynes (50) found that the conidia of *Fistulina hepatica* germinated after four years. Brefeld (5, p. 153) said that the conidia of *Fomes annosus* retained their viability for one year and a few germinated after two years of drying. He also stated (5, p. 27) that the oidia of *Phlebia merismoides* resisted drying for a month and some germinated after six months. According to Falck (15, p. 146) the aerial oidia of *Lenzites sepiaria* are resistant to drying. Oidia subjected to drying in the presence of calcium chlorid germinated after one year, and they were not killed after an exposure of several hours to 60° C. (p. 147). On the other hand, Lyman (31, p. 149) concluded that in general the retention of viability by oidia is of short duration.

The writer's results with the oidia of *Lenzites sepiaria* and *L. trabea* agree with Lyman's conclusions. Agar cultures with an abundance of oidia and oidia on glass slides were dried for varying periods. After one day of drying the percentage of germination was much reduced, and usually to less than 1 per cent. In some cases, however, a very small percentage of oidia would germinate after a few months at room temperature, perhaps because of protection of certain oidia by large masses of others. It was thought that if any resistance to drying should be manifested it would be on the natural substrate for the fungus, but the results were the same as on agar.

The chlamydospores of *Trametes serialis* proved no more resistant. It is possible, however, that the conditions under which they were formed (in a moist medium) and their previous wetting in obtaining them may render them more sensitive to drying.

ALTERNATE WETTING AND DRYING.

The oidia of *Lenzites sepiaria* and *L. trabea* do not survive alternate wetting and drying. Oidia were removed in quantities from an agar plate culture to glass slides. Two slides were retained as checks and the oidia on two others were wet with sterile distilled water and immediately put away until dry. One slide was allowed to dry under room conditions, while the other was dried in the presence of calcium chlorid. Germination tests were then made. After 16 hours the controls showed practically perfect germination, while of the wet and dried oidia three Van Tieghem cells showed less than 1 per cent and one 5 per cent germination. Repetitions of the test gave similar results.

EXPERIMENTS UPON THE DISSEMINATION OF THE OIDIA OF LENZITES SEPIARIA.

Flask cultures of *Lenzites sepiaria* and *L. trabea* obtain a much better start than cultures of the other fungi, because of the oidia. The water in the tube containing the bean-pod cultures used as inoculum becomes a suspension of oidia, and these are distributed all over the flask to start centers of growth, whereas cultures of fungi possessing no oidia can only be spread from the inoculum and consume about one month in covering all the blocks in the flask. In the light of these facts a few experiments were carried out with a view to ascertaining by what means and how easily the oidia of this fungus might aid in dissemination. It is realized that any points made here are contingent for their importance upon the question as to whether or not the oidia occur naturally. Inasmuch as Falck (13, p. 319) doubted whether wind would be of any importance in disseminating oidia, the writer set out to determine how easily the oidia might be removed from plate cultures. A new transfer was inverted over a sterile agar plate, sealed with gummed paper, and set away in the incubator. In the first test with *L. sepiaria*, an abundance of oidia were found upon the sterile agar plate after a week. Repetitions gave inconsistent results, but it was shown that small numbers of oidia may be released during their formation. Shaking a plate culture over a sterile agar plate yielded results similar to those reported by Falck (15, p. 144). Oidia were dislodged in some cases, but not in all. The same test was tried with *Collybia velutipes*, and pure cultures were obtained from oidia shaken off.

Attempts were next made to dislodge oidia from agar-plate cultures by air currents from an electric blower delivering 1.4 cubic feet per minute. The apparatus was so set up that at least a part of the oidia removed would lodge on sterile agar plates. From cultures with a very heavy development of oidia, a very few were dislodged, as determined by microscopic examination of the surface of the sterile agar plates and subsequent growth. An electric fan making a much stronger current of air removed larger, though not considerable, numbers of oidia. Oidia on wood blocks from cultures were not removed any more readily, inasmuch as they are formed only in moist atmospheres and are themselves moist and sticky. The same procedure was tried with other species showing secondary spores in culture. Individual oidia or small clusters were likewise dislodged from agar cultures of *Collybia velutipes*. The stronger current of air removed a few of the chlamydospores of *Fomes officinalis*, but oidia could not be removed from cultures of *Coniophora cerebella* or *Merulius lacrymans* or chlamydospores from cultures of *Trametes robiniophila* or *Fomes igniarius*. It is thus seen that secondary spores of most of the species mentioned do not appear to be adapted to dissemination by wind.

Oidia are readily removed by contact. Prints can be made upon glass slides or cover slips by simply allowing the glass to touch the surface of a culture. More sticky substances like agar retain more oidia than glass. The obvious application of these facts is insect dissemination, for insects with sticky feet and hairy or bristly appendages should be able to remove and carry away large numbers of the moist oidia. A cockroach caught in the laboratory was placed upon agar cultures of *Lenzites sepiaria* for a few minutes. Examination of the roach's appendages under the microscope disclosed large clumps of the oidia stuck to the tarsi. Another roach placed upon an agar culture was transferred to a sterile agar plate, allowed to remain a few seconds, and then the plate was incubated. In three days the plate showed a winding growth of *Lenzites sepiaria* and contaminations, chiefly *Penicillium*, presumably where the roach had walked over the agar during his captivity. A cockroach was then placed in a flask containing a wood-block culture of *Lenzites sepiaria* and examined after a few minutes. A few oidia were found upon the pads of the tarsi and on the bristles of the legs and antennæ (Pl. VIII, fig. 3).

Water will dislodge large quantities of oidia from agar or wood cultures. Sterile water dropped from a pipette upon the inoculum of a new transfer will carry or splash large numbers of oidia on the surrounding sterile agar.

From the above results it is concluded that oidia occurring either on wood or agar are moist, sticky spores, not adapted to air dissemi-

nation, but excellently adapted to dissemination by insects or dripping water. The practical application of these facts is obvious. If secondary spores occur outside of artificial cultures, there is no place more suitable for their formation than in the structures of wet occupancy referred to. In these structures, where conditions are moist, there would be insects or animals, such as sow bugs and cockroaches, and there is commonly dripping water, precipitation water upon cool masonry, around cold-water pipes, etc.

OCCURRENCE IN BUILDINGS OF THE SECONDARY SPORES OF THE FUNGI STUDIED.

The step following the demonstration that oidia can disseminate fungi, such as *Lenzites sepiaria* and *L. trabea*, is to prove that such oidia occur naturally in buildings. The outstanding fact is that many European writers have suggested the importance of the secondary spores in the economy of the fungus, if found naturally, and that no one has yet reported such occurrences. The writer has little information on the subject. The only secondary spores found in mills are the chlamydospores on the mycelium overgrowing the gills of fruit bodies of *Lentinus lepideus* (Pl. V, fig. 6). These are formed quite abundantly, but thus far nothing is known of their ability to disseminate the fungus. The spores which the writer found were on old fruit bodies, and tests as to their ability to germinate failed. There is, of course, the possibility that freshly formed chlamydospores may germinate, and, if so, they would disseminate the fungus much as do the basidiospores which are overgrown and imprisoned by the chlamydosporic mycelium. This means of dissemination would appear to be not so efficient a method as by the basidiospores which they replace, because the basidiospores should be lighter and hence capable of wider dissemination.

It is known that certain fungi do form superficial mycelium within the structures referred to in these studies as well as out of doors. Falck (15, p. 154) relates that the fruit-body-forming mycelium (*fruktifikative Oberflächenmycel*) of *Lenzites sepiaria* is found on moist places on beams, and he states (15, p. 143) that it is capable of producing oidia, although he has not reported the finding of these oidia in buildings. The writer has examined some superficial mycelium of *Lenzites sepiaria* and *L. trabea* upon planks secured from mill roofs, but the presence of oidia or chlamydospores as yet has not been definitely established.

SUMMARY.

In textile and paper mills prevailing conditions of humidity and temperature provide a favorable environment for the development of wood-decaying fungi. Under such conditions poorer grades of

timber, such as inferior southern pine, spruce, and hemlock, which have been used in mill construction in recent years, are readily attacked and destroyed. Hence, the losses through decay by a certain group of fungi are large. Because of the practical importance under mill conditions of *Lenzites sepiaria*, *L. trabea*, *Trametes serialis*, *Fomes roseus*, and *Lentinus lepideus*, studies upon the physiological relations of the basidiospores, mycelium, and secondary spores were undertaken, particular attention being paid to those factors influencing intramural dissemination.

All five of these fungi have been found fruiting more or less commonly upon mill roofs or in basements. *Lenzites sepiaria* and *L. trabea* do more damage to coniferous roof timbers than has heretofore been reported.

The basidiospores of the five fungi will germinate upon various agars, or wood, in tap water, and irregularly in distilled water.

At 40° C. the basidiospores of *Lenzites sepiaria* will germinate in large percentages, while those of *L. trabea* and *Fomes roseus* give small percentages. The spores of the other two fungi will not germinate at this temperature. The optimum temperatures for rapidity of germination are: *Lenzites sepiaria*, 32° to 35° C. (89° to 97° F.); *L. trabea*, 28° to 32° C. (82° to 89° F.); *Trametes serialis*, 30° to 32° C. (86° to 89° F.); *Fomes roseus*, 28° to 32° C.; *Lentinus lepideus*, 28° C. Large percentages of the spores will germinate at the lower temperatures within the range of growth for each fungus if sufficient time is allowed. The percentage of germination is the criterion which best shows the effect of temperature upon the viability of the spores.

Diffused light did not affect the germination of the spores. The basidiospores of these fungi would not germinate in direct sunlight in May, and after two days of exposure few or no spores would germinate when put in the dark. Two days of direct sunlight in May acting upon dry spores usually killed all but a very small percentage, if not all of them. The germ tubes showed no phototropic responses.

In drying tests, basidiospores of *Trametes serialis* and *Lentinus lepideus* (aged 10 days and 7 months, respectively) were killed in about 10 weeks' exposure at 28° and 32° C. (82° and 89° F.) and in about a month at 36° C. (97° F.). With fresh spores at 40° C. (104° F.), *Lenzites sepiaria* survived two months and *Trametes serialis* six weeks in an unfinished test. Spores of *Fomes roseus* five months old were killed in one week at the same temperature.

Alternate wetting and drying is destructive to the spores of these fungi. This applies either to the wetting with free water or exposure to atmospheric moisture and subsequent drying.

Basidiospores of *Lenzites sepiaria* gave a germination of 25 per cent after 2 years and 10 months of storage in an ice box; those of

L. trabea 50 per cent after 1 year; spores of *Trametes serialis* 2 per cent after 4 years and 3 months; those of *Fomes roseus* less than 1 per cent after 18 months; and those of *Lentinus lepideus* less than 1 per cent after 2 years and 7 months.

All but *Fomes roseus* have the ability to cast large numbers of spores and are shown to be capable of doing so within buildings. *Lenzites sepiaria* cast spores six times in experiments upon the ability of the sporophores to survive successive wetting, casting, and drying. A fruit body of *Trametes serialis* in the dark in the fungus pit cast spores for 15 days successively.

Observations upon fruit bodies of *Trametes serialis* in the bottom of a closed fungus pit showed that slight convection currents of air carried spores upward and throughout the pit. In mills, air currents caused by machinery, humidifiers, and heating pipes are of importance in disseminating spores cast into the air. Sow bugs were observed in this pit beneath the sporophores and were found to bear large numbers of the spores upon their bodies and appendages. The possible importance of insects and other animals in the dissemination of these wood-destroying fungi is suggested.

A description of the macroscopic and microscopic characters of malt-agar cultures of the fungi, with a key for identification, is given.

The cardinal temperatures for mycelial growth were found to be as shown in Table 5.

TABLE 5.—Cardinal temperatures for the growth of the mycelium of certain wood-destroying fungi.

Species.	Cardinal temperatures (° C.).		
	Minimum.	Optimum.	Maximum.
<i>Lenzites sepiaria</i>	About 8...	30 to 34....	Above 40.
<i>Lenzites trabea</i>.....	.....	28 to 30....	Little above 36.
<i>Trametes serialis</i>	About 3...	28.....	Between 32 and 37.
<i>Fomes roseus</i>	Below 4...	30.....	Above 36.
<i>Lentinus lepideus</i>	About 8...	28.....	Between 36 and 40.

Secondary spores of certain hymenomycetes have been reported by several writers as occurring naturally, and their importance in the economy of the fungi has been suggested. Studies were made upon the secondary spores of four of the fungi under consideration in view of their possible occurrence in a mill environment. Oidia and few chlamydospores were found in agar cultures of *Lenzites sepiaria*, and oidia also in wood cultures, and both kinds of spores in agar cultures of *L. trabea*. Chlamydospores were found in agar cultures of *Trametes serialis* and *Lentinus lepideus*.

Certain of the physiological relations of the oidia of *Lenzites sepiaria* and *L. trabea* and the chlamydospores of *Trametes serialis*

were studied. The germination temperatures corresponded closely with those of the basidiospores of the respective species except that the oidia germinated better at the higher temperature tried. Diffused light had no effect upon germination. Ten hours of direct sunlight in May prevented the germination of the secondary spores studied. Neither the oidia nor the chlamydospores resisted drying nor alternate wetting and drying.

The oidia of *Lenzites sepiaria* and *L. trabea* are essentially sticky and were found not to be adapted to dissemination by air currents. They are, however, adapted to dissemination by insects and water. This adaptation may possibly be of some importance in case oidia are found to produce naturally in mills. Thus far, however, the only secondary spores of these fungi found in mills are the chlamydospores of *Lentinus lepideus* upon the fruit bodies.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1054

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

March 11, 1922

COMPARISON OF CORN OILS OBTAINED BY EXPELLER AND BENZOL EXTRACTION METHODS.

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INTRODUCTION.

The production of oil from corn germs resulting from the manufacture of hominy, starch, glucose, and sirup has become a well-established industry in the United States. The methods of obtaining the oil from corn germs, also the economic relation of its production to the manufacture of corn products in general, the utilization of the oil, and its future in the vegetable-oil industry of this country have been described in a bulletin of the Department of Agriculture (43).¹ Later, a technical study was made of methods for refining corn oil for edible purposes, and a second bulletin was published giving the cost of refining, together with plans and estimated cost for a refinery (44).

The present paper deals with still another phase of the corn-oil industry, that of extracting the oil by means of a solvent. With few

¹ The serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

exceptions vegetable oils in the United States are at present obtained from the various oleaginous materials by means of pressure. In the case of cottonseed oil the hydraulic press is universally used, while in the production of oil from corn germs the oil expeller has been everywhere adopted. In European countries the extraction of vegetable oils has been to a considerable extent by means of organic solvents, and within the last decade this method has been receiving increasing attention in this country. The success of this method, provided it is found acceptable from an economic standpoint, depends in the case of edible oils largely on whether the oil produced thereby can be freed from the solvent so thoroughly that its flavor will not be affected. This method is finding some application in the production of corn oil and is being considered both for extracting the oil from the germs directly and for extracting the residual oil from the so-called oil cake, or expeller cake.

In the present paper comparison is made of the general characters and quality of three types of corn oil which have been prepared from the same general lot of material so as to make their source comparable. The three types are as follows: (1) Oil produced by expellers at the plant, (2) oil extracted with benzol from germs from the same source, and (3) oil extracted with benzol from the oil cake obtained from the first-mentioned process. These oils were neutralized, bleached, and deodorized, their physical and chemical constants determined, and their color, odor, and taste compared. Such a comparison should show whether there is a possibility of preparing corn oil by benzol extraction that will be equal to that produced by the expeller method.

CHARACTER AND COMPOSITION OF CORN OIL.

Like most vegetable oils which have acquired economic prominence, corn oil has been the subject of much study and investigation. The literature shows that such investigations have been mainly along three distinct lines: (1) Its composition and physical and chemical constants, (2) the methods of its production and its economic relationship to the manufacture of corn products in general, and (3) its uses in the industries. In order to show briefly the extent and character of these investigations, a résumé of the literature is herewith given.

REVIEW OF PREVIOUS INVESTIGATIONS.

The first investigation of corn oil seems to have been published in 1822 by Bizio (6), who describes the oil as a reddish yellow liquid with a faint vanilla odor and balsamic taste, one constituent of which resembles stearin. In 1832 Cartis (8) called attention to the oil ob-

tained from corn during the distillation of brandy, which he found suitable for lamp oil and as a substitute for linseed oil in paints. The first investigation of the composition of the oil appears to be that reported in 1866 by Hoppe-Seyler (20), who found that the saponifiable fat of the corn contains stearin, palmitin, and much olein. Investigations of the oil followed rapidly after this. In 1867 Allemann (2) confirmed the presence of palmitic and stearic acids. König (23) in 1871 reported that the oil obtained by ether extraction was at first a colorless liquid, but on standing became solid and quite yellow in color, from which he concluded that the oil belonged to the class of drying oils.

The methods of obtaining the oil from corn also began to receive notice. In 1880 Schulz (41) described a method of removing the oil from corn mash, and in the next year Leeuw (24) suggested the removal of the germ from the remainder of the cracked kernel by flotation in brine of 15° Bé. Maisch (27) in 1885 called attention to the fact that corn oil was being used to some extent as a lubricant and for soap making. In the following year (1886) Shuttleworth (42) reported on the specific gravity of the oil. In the same year we find the first mention of the oil produced by hydraulic pressure when, according to Wiegand (53), Trimble discussed the physical properties of such an oil. Spüller (48) in 1887 published the results of a detailed study of the composition of an ether-extracted oil. He reported no free acids and no oxygen absorption in 14 days. A year later Lloyd (25), while discussing some of the characteristics of corn oil, reported that as early as 1876 an attempt was made to extract the oil from corn with carbon bisulphid, the purpose being to furnish extracted meal for the distilling industries, but that the venture was abandoned. At the same time Hazura (13) reported some work on the iodine number of the oil, and the following year Bowers (7) suggested the adaptability of the oil for pharmaceutical preparations, but found that it emitted disagreeable odors on heating, which, he states, would make it unsuitable for frying purposes. In 1889 Kennedy (21) and also Heinitsh (16) suggested the use of the oil for pharmaceutical preparations. Stellwaag (49) in 1890 reported on the constants of corn oils extracted with ether and petroleum ether, respectively. In 1891 De Negri and Fabris (30) studied the constants of corn oil, and a year later Smith (46) published what appears to be the most detailed investigation of the oil up to that time, his report including its physical and chemical constants, its reaction with alkalis with special reference to soap making, and its application as a lubricant. In 1893 Hart (12) and Smetham (45) both reported on the constants of the oil. The following year (1894) De Negri and Fabris (31) published their second note on the oil and Rokitsansky (38) isolated linolic acid from it.

From 1894 to 1898 corn oil was subjected to much study, reports on its physical constants being published by Hehner and Mitchell (15), Dulière (9), and Hehner (14). In 1898 Hopkins (19) made an extensive study of the oil and Procter (34) reported on its physical constants and Wiley and Bigelow (54) determined the calories of the oil.

In 1899 Winfield (55) published a monograph, including a review of the literature and the results of her study of the oil. At about the same time Archbutt (3) reported the oil as semidrying and unsuitable for lubricating purposes. The following year Morpurgo and Götzl (29) found that corn oil is difficult to detect in cottonseed oil and in 1901 Vulte and Gibson (51) determined the constants of the oil and claimed to have confirmed the presence of hypogæic, arachidic, acetic, and formic acids. In 1903 a comparison of olive oil with corn oil was made by Tolman and Munson (50), and Moore (28) studied the digestibility of the oil. In the same year Gill and Tufts (10) suggested that the presence of sitosterol in corn oil might serve as a means of identifying it when present in other oils. The same authors (11) also published during the year their investigation of the unsaponifiable matter. The possibility of corn oil being used as an adulterant in lard was investigated by McPherson and Ruth (26) in 1906. Two years later Ritter (36) claims to have found the oil equal to olive or cod-liver oil in the treatment of tuberculosis.

In 1909 Wagner (52) published an account of the development of the corn-products industry, in which he refers to some of the technical uses of corn oil and Olig and Brust (32) reported on the constants of nine samples of corn oil. The refractive index of the oil received the attention of Klimont (22) in 1911 and Smith (47) in 1912. The following year an editorial (1) in the *Seifensieder-Zeitung* suggested the use of the oil for edible purposes and Pool and Sayre (33) studied the oil with a view toward its substitution for olive and cottonseed oils in pharmaceutical preparations. In 1915 the constants were again reported on by Backer (4) and Sayre (39) found its drying properties to be greatly inferior to linseed oil.

The adaptability of corn oil to cooking and baking and for general edible purposes was pointed out by Sayre (40) in 1916. The digestibility of corn oil was found to be similar to that of cottonseed oil and somewhat greater than that of lard by Rockwood and Sivickes (37) in 1918, and in the same year Holmes (17) found the oil to be digestible and suitable for food purposes. The following year Holt, Courtney, and Fales (18) also reported favorably on the digestibility of the oil and its food value. In 1920 Rabak (35) studied the effect of mold on the composition of corn oil and reported that the mold apparently feeds on the oil, causing the latter to disappear gradu-

ally and modifying its composition. The most recent work on corn oil is that by Baughman and Jamieson (5), 1921, who found the following acids to be present: Oleic, 43.4 per cent; linolic, 39.1 per cent; palmitic, 7.3 per cent; stearic, 3.3 per cent; arachidic, 0.4 per cent; and lignoceric, 0.2 per cent. For purposes of comparison the physical and chemical constants of corn oil as reported by the various investigators are summarized in Table 1.

	° 9243	13 9213	41.4766	118.6 { 147.6 124.5	11.49 20.58 22.75	192.6 188.11 180.8	2.4 1.128	92.23	4.2	27.74	72.76	18 to 20	135.97 (arachidic found).	1.69 1.43	(13)
Archbutt															
Windsor															
Morpurgo and Gitel															
Vulste and Gibson															
Talman and Mun- son	13 9253	141.4768		123.3 (Hübl)		189.9	3.65			7.44		21.6	134.5		
Olig and Brust	.9233- .9272			112.5- 128.1		188.7- 191.3 192.6		92.6- 95.3						.6 to .9	
Klimont															
Smith				1.4745 { 1.4675 1.4677											
Baker	4 922	1.471		110.0 (Wijis)		192.0	.46								
Pool and Sayre				-10 to -15.											
Rabak 1	14 9204	141.4712		121.0 (Hübl)	15.3	190.3	6.84	93.6	12.8					4.13	
Bauchman and Jamieson 15	16 9185	141.4717		117.2 (Hanus).		187.3	1.25							1.7	

1 Faint vanilla odor, balsamic taste.

2 Oil extracted with ether.

3 No oxygen absorption in 14 days.

4 At 15° C.

5 Extracted oil.

6 At 60° F.

7 First oil extracted with ether; second oil extracted with petroleum ether.

8 Fusion, 13° to 20° C.; solidification, 13° to 16° C.

9 Starchy odor, mild taste.

10 Fusion point.

11 Oxygen absorption, 4 per cent.

12 At 15.5° C.

13 Oil is semidrying.

14 At 23° C.

15 The oil was obtained from dry-process germs with an expeller.

16 At 25° C.

17 At 20° C.

Oleic, linolic,
palmitic, ste-
aric, arachi-
dic, ligno-
ceric.

EXPERIMENTAL WORK.

METHOD OF SELECTING MATERIAL.

In order to make a logical comparison of the oils obtained by both the expeller and the benzol extraction processes it was necessary that

both types of oil should be obtained from the same lot of germs. The material used in the experiments was obtained from typical hominy and glucose plants, the former producing dry-process germs and the latter wet-process germs. A day was spent in one plant of each type, and the material was collected, a little at a time, during a period of about seven hours. In this way approximately 150 pounds each of the germs and oil cake and about 5 gallons of expeller oil were obtained. This method of collecting the material gives reasonable assurance that the three types of oil, namely, the expeller oil and the oils extracted with benzol from the germs and from the

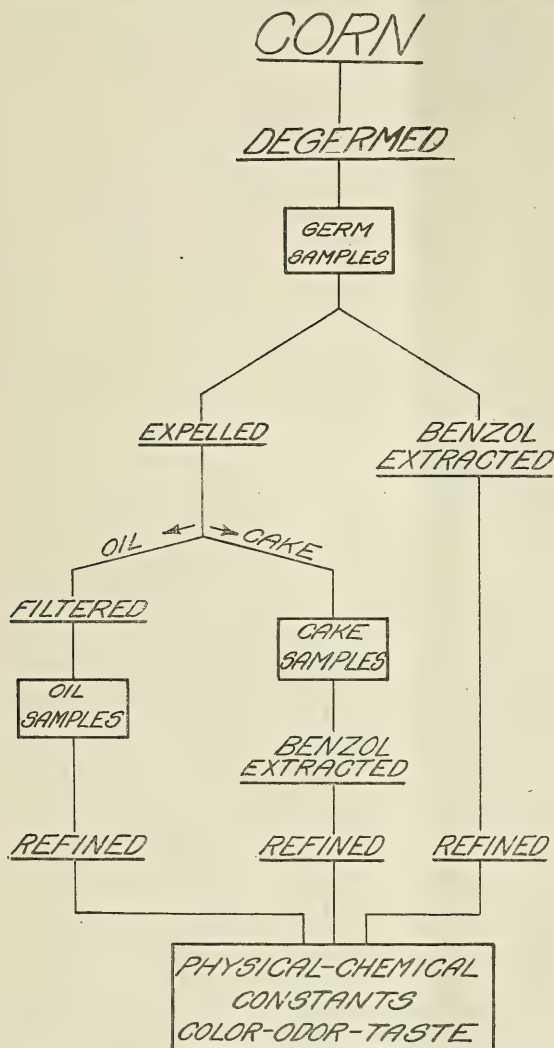


FIG. 1.—Diagram showing the method of collecting corn material for the extraction of oil. This system was used in connection with both dry-process and wet-process germs.

cake, are derived from approximately the same germ stock. Figure 1 shows graphically the plan according to which the material was collected.

BENZOL EXTRACTION OF CORN GERMS AND OIL CAKE.

The germs and oil cake were ground to a suitable degree of fineness, and 50 pounds at a time were extracted in a large, heavy, gal-

vanized-iron can, in the center of which was a 1-inch glass tube extending below a false bottom. The false bottom consisted of a screen of one-fourth-inch wire covered with several thicknesses of light, coarsely woven cloth. The material was packed on this false bottom and the benzol allowed to percolate through it into the bottom of the can, from which it was removed by means of the tube. The benzol used in all the extractions was a pure so-called water-white grade, which could be distilled completely on a steam bath at a temperature not exceeding 85° C. The first extract was reserved and a new batch of solvent added. The latter was allowed to pass twice through the material and then set aside. A new batch of solvent was added and allowed to pass four times through the material. No further extraction was made, although the material still contained considerable oil, especially the wet-process germs. Table 2 shows the quantity of oil present in the several materials before and after extraction.

TABLE 2.—*Percentage of oil in the wet-process and dry-process germs and in the oil cake before and after extraction with benzol.*

Material.	Percentage of oil present.	
	Before extraction.	After extraction.
Germs:		
Wet process.....	50.6	7.3
Dry process.....	23.4	3.1
Oil cake:		
From wet-process germs.....	13.5	2.8
From dry-process germs.....	5.2	1.2

The quantity of oil remaining in the material after the extraction with benzol, especially in the wet-process germs, was considerably greater than would be the case in commercial practice.

REMOVAL OF THE SOLVENT.

The last two benzol extracts obtained were mixed, and by heating the extract on a steam bath under partial vacuum approximately 90 per cent of the benzol was removed. The residue of oil, together with the remaining benzol, was then added to the first extract, which contained the bulk of the oil removed from the material. From this mixture the benzol was distilled as thoroughly as possible in the way described. The last portions of the solvent were then removed by passing a current of dry steam into the mixture under reduced pressure. This treatment was continued until no more benzol collected in the receiver. The oil thus obtained still had a very slight benzol odor. If small quantities of water collected in the flask, this was removed from the oil by settling, with subsequent filtration if necessary.

A serious difficulty encountered in the removal of the solvent was the tendency of the oils to foam when the last portions of the benzol were being removed. This foaming was much more severe in the extracts from the dry-process germs, due possibly to the presence of more starchy matter in such material than in the germ stock separated by the wet process, in which all the starch is removed by thorough washing. The presence of the starch also makes the benzol extracts from the wet-process germs exceedingly difficult to filter.

For purposes of convenience the several oils will hereafter be designated as follows: *A*, Wet-process germ by expeller; *B*, wet-process germ by solvent; *C*, wet-process cake by solvent; *D*, dry-process germ by expeller; *E*, dry-process germ by solvent; *F*, dry-process cake by solvent.

APPEARANCE AND CHARACTER OF THE CRUDE OILS.

Samples of the two expeller oils and the four benzol-extracted oils were placed in standard 5½ inch bottles for the purpose of comparing the color and other characteristics. Some of the oils, especially the benzol-extracted oils from the oil cake, appeared to be somewhat turbid when cold, although they were filtered clear while warm. For this reason the samples were allowed to stand in a dark place for a month and their condition then noted. Table 3 summarizes the appearance of the oils.

TABLE 3.—*Color and appearance of crude corn oils in standard 5½-inch bottles after standing in the dark for one month.*

Oils. ^a	Color.	Clarity, deposit of solids, etc.
Sample D, dry-process germ by expeller...	Bright golden.....	Very slight whitish deposit.
Sample E, dry-process germ by solvent....	do.....	About ¼-inch whitish deposit.
Sample A, wet-process germ by expeller....	Bright golden, with reddish tinge.	Very slight whitish deposit.
Sample B, wet-process germ by solvent...	Slightly more reddish than oil A.	About ½-inch whitish deposit.
Sample F, dry-process oil cake by solvent.	Reddish yellow.....	¾-inch dark brown deposit.
Sample C, wet-process oil cake by solvent.	Reddish brown.....	¾-inch light brown deposit.

^a The samples of oil are arranged according to their depth of color, lightest to darkest.

It will be noted that the oils from the dry-process material are on the whole somewhat lighter in color than the other oils. However, the same oils also appear to have the heaviest deposits of solids. While, no doubt, some stearin is present in these deposits, yet from the fact that the oils from the dry-process germ material contain the heaviest deposits it may be assumed that a portion of these solids is starchy material. The benzol-extracted oils from the oil cakes deposit by far the greatest quantity of solid matter.

The free fatty acid content of each of the oils was determined, and the results are shown in Table 4.

TABLE 4.—Percentage of free fatty acids in crude corn oils.

Oils.	Percentage of free fatty acids.	Oils.	Percentage of free fatty acids.
Sample A, wet-process germs by expeller.....	1.76	Sample D, dry-process germs by expeller.....	1.72
Sample B, wet-process germs by solvent.....	2.15	Sample E, dry-process germs by solvent.....	1.90
Sample C, wet-process oil cake by solvent.....	3.60	Sample F, dry-process oil cake by solvent.....	1.88

It is of interest to note that the oils from the dry-process germs (D, E, and F) are uniformly lower in free fatty acids than the oils from the wet-process germs. There appears to be practically no difference between the free acidity of the benzol-extracted oils and the expeller oil of this group. In the case of the oils from the wet-process germs (A, B, and C), the benzol-extracted oils contain more free fatty acids than the expeller oil. This is especially true of the oil extracted from the oil cake (C).

REFINING² THE OILS.

The six foregoing oils were refined as nearly alike as their individual character would permit. The bleaching and deodorizing were done in the same way in the case of each oil, but the method of neutralizing with caustic required some modifications with certain of the oils. It was the intention to treat all as nearly alike as possible, so that whatever differences might be noted in their quality after refining could logically be assumed to be due to the inherent differences in the oils obtained by the two methods of removal from the germ.

NEUTRALIZATION WITH CAUSTIC.

After a number of preliminary experiments it was found that the method of neutralizing the oils with caustic described in a previous publication (*44*) seemed likely to give the most generally satisfactory results on the oils as a whole. After the preliminary experiment, 5-pound batches of oil were used in each case. The method used was as follows:

To the cold oil there was added slowly, while stirring, sufficient 14° B₆ sodium hydroxid to neutralize the free fatty acids present plus 50 per cent excess. After being stirred for 10 minutes the oil was slowly heated while the stirring was continued and the temperature raised to 55° C., until the oil broke. After the break 2 per cent of powdered soda ash was added gradually and the stirring continued for 5 minutes longer. The oil was then kept for 3 hours at a temperature of 50° C., after which it was allowed to cool over night and then drawn off from the deposited soap stock. Channels were cut

²The term "refining" as here used includes the three main operations usually employed in making edible oils: (1) Neutralization with caustic, (2) bleaching with fuller's earth, and (3) deodorizing with steam.

in the soap stock and the oil, which drained into these channels upon warming, was removed from time to time until no more could be separated.

All the oils, except F, were treated in the manner described. The time required for the oils to break varied somewhat, oils D and E requiring about 30 minutes to acquire a good break, and oils A, B, and C slightly longer. Oil F presented some difficulty, owing to the presence of mucky, solid matter, and in order to make it break within a reasonable time an additional 50 per cent excess of 14° Bé. sodium hydroxid had to be added. Table 5 shows the refining losses resulting from this treatment.

TABLE 5.—*Refining losses and condition of the soap stock resulting from the neutralization of corn oils.*

Oils.	Refining loss (per cent).		Character of soap stock.
	After first draining.	After final draining.	
Sample A, wet-process germs by expeller.	9.58	5.65	Sufficiently firm to permit channeling.
Sample B, wet-process germs by solvent.	8.27	6.58	Do.
Sample C, wet-process oil cake by solvent.	14.13	12.71	Slimy; occluded considerable oil which can not be recovered to any extent by channeling.
Sample D, dry-process germs by expeller.	5.08	3.69	Same as oil A.
Sample E, dry-process germs by solvent.	6.84	6.49	More slimy than oil D.
Sample F, dry-process oil cake by solvent.	15.0	15.0	Very slimy; no oil can be removed by channeling.

It is found that in the case of both wet-process and dry-process germs the neutralization of the benzol-extracted oil results in a higher refining loss than with expeller oil and that this greater loss is not accounted for by any corresponding difference in the free fatty acid content. In the case of benzol-extracted oils not so much oil can be recovered by channeling the soap stock as is the case with expeller oils. The soap stock from the solvent oils is slimy and occludes more oil than the soap stock from the expeller oils, and this oil can not be recovered to any great extent.

By reference to Table 4 it will be noted that the amount of free fatty acids present will not account for the difference in the refining losses obtained in the oils from wet and dry process germs. Thus solvent oil B from wet-process germs with 2.15 per cent free acids showed about the same refining loss as solvent oil E from dry-process germs which contained only 1.9 per cent of free acids. In the case of the expeller oils from these two types of materials the free fatty-acid content was about the same, yet the oil from the dry-process germs showed a much smaller loss. It is probable that the presence of the substances which cause the foaming of the benzol

extracts of the oils from dry-process germs and retard their filtering are accountable for the greater refining losses in such oils. In the case of the extracted oils from the cake the same condition exists, and a lower refining loss was experienced with oil C than with oil F, although the former contained practically twice as much free fatty acids.

The free fatty-acid contents of the oils after treatment with caustic are given in Table 6.

TABLE 6.—*Quantity of free fatty acids in corn oils after treatment with caustic.*

Oils.	Free fatty acids.	Oils.	Free fatty acids.
	<i>Per cent.</i>		<i>Per cent.</i>
Sample A, wet-process germs by expeller.	0.039	Sample D, dry-process germs by expeller.	0.033
Sample B, wet-process germs by solvent.	.050	Sample E, dry-process germs by solvent.	.053
Sample C, wet-process oil cake by solvent.	.058	Sample F, dry-process oil cake by solvent.	.066

It will be noted that after the treatment with caustic the oil contained only a very slight percentage of free fatty acids. The color of all the oils made directly from the germs was quite satisfactory, and oils prepared by benzol extraction did not show to disadvantage as compared with the expeller oils. The oils extracted from the oil cake were, of course, considerably darker than the others, the same general color relationship being evident as that which existed in the crude oils. The color of the oils after the treatment, as read on the Lovibond scale, is included in Table 7 for the purpose of comparison with that from the finished oils.

BLEACHING WITH FULLER'S EARTH.

All the oils were treated exactly alike during the process of bleaching with fuller's earth. The procedure used was as follows:

The oil was heated slowly, with constant stirring, to 110° C., at which temperature it was held for 15 minutes. Then 5 per cent of standard fuller's earth^a was added and the stirring continued for 10 minutes, at a temperature of 105° to 110° C. The oil was then rapidly filtered on a force filter.

The effect of this treatment on the color of the oils is shown in Table 7 in connection with the discussion of the bleaching effect of the deodorizing treatment.

DEODORIZING.

The deodorizing of the oils was accomplished in half-liter lots in glass flasks by blowing with a current of dry steam at 225° C. (437° F.) for two hours under a vacuum of 25 inches. This treatment had

^a Standard fuller's earth is recommended by the American Oil-Chemists' Society for bleaching vegetable oils and may be obtained from the secretary of that society.

a noticeable bleaching effect on all the oils. In order to show the relative bleaching effected in the several oils by this and the other processes the color readings are summarized in Table 7.

TABLE 7.—Color readings of corn oils in standard 5½-inch bottles with the Lovibond scale after treatment with caustic, bleaching with fuller's earth, and deodorizing.

Oils.	Color (35 yellow in each case).		
	After treatment with caustic.	After bleaching with fuller's earth.	After deodorizing.
	Red.	Red.	Red.
Sample A, wet-process germs by expeller.....	6.6	3.5	3.0
Sample B, wet-process germs by solvent.....	5.2	4.0	3.5
Sample C, wet-process oil cake by solvent.....	16.0	10.0	10.2
Sample D, dry-process germs by expeller.....	4.5	1.6	1.5
Sample E, dry-process germs by solvent.....	5.8	3.6	2.2
Sample F, dry-process oil cake by solvent.....	14.0	8.0	5.6

It is of interest to note that the benzol-extracted oils from the germs contained only slightly more red than the expeller oils. On the whole the oils from wet-process germs are darker than those from dry-process germs. The oils extracted from the oil cakes are naturally considerably darker than the others, that from the dry-process cake bleached much more than that from the wet-process cake; in fact, the latter oil is the only one in the entire group in which the color would be likely to interfere to any extent with its use as an edible oil.

COMPARISON OF THE FINISHED OILS.

PHYSICAL AND CHEMICAL CONSTANTS.

In order to show whether the six oils under discussion differed to any extent as regards the usual physical and chemical constants, these constants were determined and the results summarized in Table 8.

TABLE 8.—Comparison of some physical and chemical constants of the finished corn oils.

Oils.	Specific gravity.	Index of refraction.	Iodin number (Hanus).	Acid number.	Saponification number.	Acetyl number.	Acids.				
							In-soluble Hehner number.	Liquid.	Solid.	Reichert-Meisel number.	Solidifying point of the mixed acids.
	At 25° C.	At 25° C.						Per ct.	Per ct.		° C.
Sample A.	0.9181	1.4723	122.8	0.078	191.7	9.26	95.07	91.27	9.73	0.352	16.6
Sample B.	.9186	1.4726	121.6	.10	189.6	9.81	95.04	91.10	9.90	.312	16.8
Sample C.	.9185	1.4733	123.0	.116	183.0	10.93	92.60	89.96	10.04	.378	16.5
Sample D.	.9177	1.4726	124.8	.066	187.2	7.26	95.06	89.82	10.18	.115	16.0
Sample E.	.9165	1.4732	121.2	.106	194.2	9.99	93.00	89.88	10.12	.190	16.3
Sample F.	.9179	1.4731	125.5	.123	197.5	10.58	92.40	89.61	10.39	.135	16.5

In so far as is indicated by the physical and chemical constants these six oils do not appear to differ to any great extent. Such differences as exist are not any greater than would be expected in several samples of normal oil. Neither do the constants of these oils on the whole show any considerable divergence from those reported by other observers.

QUALITY OF THE OILS.

The only practicable means of judging the quality of an oil which is intended for edible purposes is by its color, odor, and taste. As already stated, all the oils except C, which was extracted with benzol from wet-process oil cake, are sufficiently light in color to make them acceptable for edible purposes. Immediately after the oils were deodorized all samples were carefully tested for general odor and taste. To the writer there appeared to be no perceptible difference between oils A, B, D, and E. The remaining two, C and F, both of which were obtained from oil cake, were quite inferior, and C was the most inferior of the entire lot. In order to obtain a more critical opinion as to the quality of these oils, small samples of each were submitted to two men engaged in practical oil refining and experienced in the judgment of edible oils. The samples were sent two or three weeks after they had been deodorized, which fact should be borne in mind when the findings of these men are considered. Besides the six oils under discussion, a sample of commercial corn oil bought in a grocery store⁴ was also submitted, designated as oil X. The entire list was numbered and submitted without any information as to their source or method of preparation except that all were corn oils. One of the judges considered all the oils except C of proper color for edible purposes. As far as odor and taste were concerned he thought he could detect traces of solvent in all the oils except A and B. Since sample B was prepared by benzol extraction and A was an expeller oil, the "off" odor could not have been due to the solvent alone. He considered all but A and B insufficiently deodorized and believed that the peculiar flavor of all but A would make them unsatisfactory for edible purposes.

The opinion of the other man was considerably different. Oil D was considered suitable for salad and B and E good enough for cooking purposes; C was declared to be exceptionally bad, and a peculiar flavor was detected in F and X. While none of the oils were considered "choice," he would rank them as follows, from best to poorest: D, B, E, A, F, X, C. This judgment would place the two solvent oils from the germs between the two expeller oils

⁴ This sample of oil was purchased at a store which has a rapid turnover, but the exact age of the sample was not known; hence its quality as compared with the experimental oils must be considered with this fact in mind.

and rank all four of them as better than the solvent oils from the cake.

After these opinions had been received the oils were again tested in the laboratory, and it was found that some deterioration had taken place in some of the oils during the five weeks which had elapsed since they were deodorized. The bottles containing the oils were not quite full and were kept during the interval in a dark place. The changes noted were greatest in the oils from the oil cake and possibly slightly greater in the benzol-extracted oils than in the expeller oils. There seems little doubt that the general quality of these oils could have been materially improved with a more thorough deodorization. The deodorization of oils in the laboratory on a small scale has certain limitations and can not quite compare with commercial operations. The vacuum obtainable in these experiments was not as great as desired, and the arrangement used for raising the oil to the proper temperature might have led to unequal heating. It is probable that a more thorough deodorization would not only improve the quality of these oils but would prevent them from deteriorating rapidly on standing.

SUMMARY.

Corn oils obtained by means of expellers and by benzol extraction from comparable samples of both dry-process and wet-process corn germs and oils obtained by benzol extraction from the expeller cake were compared as to character and quality.

Of the crude oils those extracted from the cake were the darkest and deposited the greatest amount of sediment on standing. The benzol-extracted oils from the wet-process germs contained more free acids than the oils obtained by that method from the dry-process germs, this being especially true of the oils from the cake. All the oils were refined in the same manner, with the exception of the benzol-extracted oil from the dry-process germ cake. Owing to the sediment present, this oil required a greater quantity of caustic. The oils were all deodorized by blowing them with a current of steam at 225° C. (437° F.) for two hours under a vacuum of 25 inches. This treatment removes odorous volatile constituents and in the case of solvent-extracted oils tends to remove the final traces of the solvent.

The expeller oils showed the lowest loss on treatment with caustic; in the oils obtained by benzol extraction from the germs the loss was somewhat greater, and the benzol-extracted oils from the oil cakes showed by far the greatest loss.

There were no striking differences in the physical and chemical constants of the oils either with respect to the two types of germs from which they were produced or to the method of production.

No material difference could be noted in the finished oils from the germs immediately after their preparation, but upon standing some deterioration took place, and this was somewhat more noticeable in the benzol-extracted oils than in the expeller oils.

All the oils except perhaps that obtained by benzol extraction of the cake from wet-process germs were sufficiently light in color to make them suitable for salad and cooking purposes.

The oils obtained by benzol extraction from the two types of oil cake were inferior in all respects to the oils from the germs, that from the cake from wet-process germs being the poorer of the two.

A more thorough deodorization than that to which the oils could be subjected in these experiments might eliminate the remaining traces of either benzol or other odorous constituents, which no doubt account for the slight inferiority noticed in the benzol-extracted oils from the germs.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1055

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.



May 10, 1922

METHODS OF MANUFACTURING POTATO CHIPS.

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INTRODUCTION.

Potatoes are a universal food and share honors with bread as the "staff of life." There is only one style, however, in which cooked potatoes are now distributed in commercial quantities over long distances in a condition to keep for a considerable time. Crisp, golden potato chips command a ready market in all seasons, and there are firms which supply markets a thousand miles away. Moreover, it is not difficult to prepare them at home with ordinary household equipment if a few fundamental rules are observed.

Beginning in 1914, there has been conducted each winter a series of cooking experiments designed to test the culinary value of a large number of the most promising of the seedling tubers developed in the potato-breeding project of the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry, United States Department of Agriculture. During the first three years a special study was made of methods of making potato chips and the value of the different seedlings for that purpose.

The first year's work, 1914-15, was largely experimental, methods of procedure being developed and standardized. The tests were continued and amplified during 1915-16 and 1916-17. No effort was

made to study commercial varieties systematically, but a number of the varieties from the departmental collection were tested during the course of the three years. These included several varieties from each of Stuart's¹ eleven groups or families. All of these potatoes were grown by the Office of Horticultural and Pomological Investigations on the State Experimental Farm at Presque Isle, Aroostook County, Me. Cultural and weather conditions varied somewhat during the seasons, but the comparison between different varieties is substantially correct, especially between tubers grown in any one year. The potatoes were shipped to Washington each fall and kept in cold storage at the Arlington Experimental Farm until needed. The general results obtained in the cooking tests have been summarized and are presented here.

EXPERIMENTAL METHODS OF MAKING POTATO CHIPS.

In starting these tests it was first of all important to determine the best methods of making chips, the most satisfactory frying medium, and the most efficient equipment to use. The Green Mountain variety of potato was taken as the standard of comparison. The methods employed naturally had to be those adapted to home rather than to commercial usage, because of laboratory limitations in equipment and supplies; but it was intended to make the tests comply with commercial practices in so far as it was possible.

The following recipe for potato chips by Farmer² was used as a basis for the investigation:

Wash and pare potatoes. Slice thinly (using a vegetable slicer) into a bowl of cold water. Let stand two hours, changing water twice. Drain, plunge in a kettle of boiling water, and boil one minute. Drain again and cover with cold water. Take from water and dry between towels. Fry in deep fat until light brown, keeping in motion with a skimmer. Drain on brown paper and sprinkle with salt.

The partial cooking in boiling water was supposed to keep the potato from absorbing much of the fat in which it was fried, resulting in a less greasy product and was, of course, a slightly more economical one, as less grease was consumed. The recipe was followed, with variations, during the preliminary work in 1914-15. Though good chips were secured, the method was not found to be entirely satisfactory, as it entailed too much labor. A study of the methods in use in commercial plants demonstrated that the hot-water bath was neither practicable nor necessary. The problem was to produce

¹ Stuart, William. Group classification and varietal descriptions of some American potatoes. U. S. Dept. Agr. Bul. 176, 56 p., 19 pl. 1915.

² Farmer, Fannie Merritt. The Boston Cooking-School Cook Book . . . p. 314. Boston, 1917.

first-class chips by methods as simple as possible, equally applicable at home or in a factory. The following methods were tried:

- (1) Following the recipe given above.
- (2) Washing in cold water, which was then shaken off; not dried.
- (3) Washing in cold water; dipping in hot water; not dried.
- (4) Washing in cold water; dried between towels.
- (5) Washing in cold water, dipping in hot and again in cold water; not dried.
- (6) Washing in cold salt water and then in clear, cold running water; dipping in hot water; then in cold water and dried.
- (7) Soaking in cold water for 24 hours; dipping in hot water; again in cold water; dried.
- (8) Not washed or dried; fried as soon as sliced.
- (9) Not washed; dried before frying.
- (10) Dipping in hot water immediately after slicing; then in cold; drained but not dried.

Some of these methods produced good chips. Certain others, notably Nos. 8, 9, and 10, resulted in a distinctly poor product, soggy and uneven. There was no apparent advantage from the use of the salt-water bath in No. 6. Nor was it found that the hot-water bath was at all essential to producing crisp, nongreasy, high-grade chips. Cutting the potatoes into thin, even slices with an accurate vegetable slicer, soaking them thoroughly in clear, cold water after an initial bath of cold running water, and frying them in a clean, high-grade fat at a high temperature were found to be the three essentials in producing crisp, high-quality chips.

FATS USED IN THE EXPERIMENTAL WORK.

Deep-fat frying to the minds of many housekeepers means frying in lard, and many cookbook recipes for potato chips specify the use of lard. Pure leaf lard, therefore, headed the list of fats which were experimented with. Then came various lardlike derivatives of cottonseed oil, half a dozen standard brands of cottonseed oil, several samples of peanut oil, coconut oil, and a mixture of lard and beef suet.

The most satisfactory frying medium was found to be a high-grade cottonseed oil, and this was adopted as the standard in subsequent cooking tests. Good cottonseed oil was clear and bland and practically flavorless. It proved to be the most economical fat, both because of a lower initial cost and a minimum of waste in cooking; and a comparison of chips fried in the different fats demonstrated its superiority in behavior during cooking and in the flavor of the finished product. Both the lard and the lard and suet mixture imparted a flavor or aftertaste that was unpleasant to some people and left a cloudy coating on the chips that made them less attractive than the clear yellow-brown gloss of chips fried in oil. All the vege-

table oils and compounds were more satisfactory than the animal fats. The liquids were preferred to the semiplastic compounds, being more convenient to use in quantities, less expensive, and less wasteful in utilization.

Most manufacturers of commercial potato chips use cottonseed oil, a few use lard, and a few have experimented with coconut and corn oils. Peanut oil is not yet widely known and has been so far little used in the manufacture of potato chips, but there is no reason why satisfactory results should not be obtained if a highly refined, bland oil is put on the market at prices that will compete with the cottonseed oil now in use.

The smoking point of well-refined cottonseed oil is higher than that of most of the other frying mediums, a much more important factor

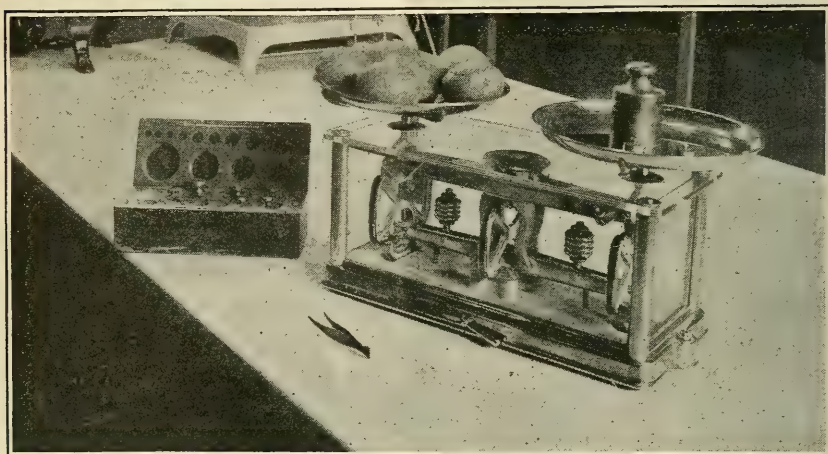


FIG. 1.—First step in making potato chips. Weighing six medium-sized potatoes on a torsion balance.

in frying potato chips than in frying doughnuts, fritters, or similar foods that must be cooked through as well as browned. Blunt and Feeney³ have determined the burning point of a number of the cooking fats, and their investigations show that cottonseed oil has the highest burning point, 451° F. (232.7° C.), with two cottonseed oil derivatives very nearly the same, 450° F. (232.2° C.), and 448° F. (231.1° C.). Leaf lard smoked at 430° F. (221.1° C.), bulk lard at 381° F. (194.0° C.); olive oil at 347° F. (172.7° C.); two samples of peanut oil at 323° F. (161.6° C.) and 300° F. (148.8° C.), respectively; and coconut oil at 277° F. (136.1° C.).

Some of the samples of peanut oil used in these investigations were almost as highly refined as the cottonseed oil and had as high a smoking point, but others smoked at approximately as low a temperature

³ Blunt, Catharine, and Feeney, Clara M. The smoking temperature of edible fats. In *Jour. Home Econ.*, v. 7, No. 10, pp. 535-541. 1915.

as the two samples used by Blunt and Feeney. The coconut oil used in the chip experiments of the United States Department of Agriculture smoked at a temperature of 338° F. (170° C.), higher than the



FIG. 2.—Removing eyes and diseased spots from peeled potatoes.

figures given by Blunt and Feeney, but still too low for satisfactory results. Olive oil was not tried; its expense prohibits its use as a commercial frying medium. According to Blunt and Feeney, however,

its smoking point is too low to make it a competitor of the cheaper oils. No fat with a smoking point of less than 220° C. (428° F.) is desirable for frying potato chips. Overheated fat is unwholesome and imparts a scorched flavor to the food.

STANDARD METHOD OF MAKING CHIPS FOR THE TESTS.

As a result of the first year's experiments, the following uniform method of procedure was developed and used as a standard:

Six or seven medium-sized potatoes, with a total weight of approximately 1,000 grams, were first weighed on a torsion balance (fig. 1), then peeled in a vegetable peeler, all eyes or diseased spots removed (figs. 2 and 3), and the peeled potatoes weighed again. They were then sliced with a vegetable cutter into slices one-sixteenth of an inch thick; these slices were weighed (fig. 4) and put to soak in cold water, care being taken to keep each lot or variety in a separate pan. Each lot was washed in cold running water until the next lot had been weighed, peeled, sliced, and weighed again. It was then placed in a pan of cold water, while the second lot took its place under the faucet of running water (fig. 5). By the time the last lot had been prepared and placed under the faucet, the first lots had been soaking in cold

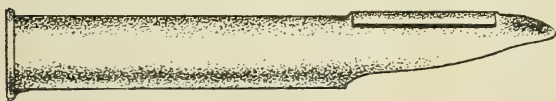


FIG. 3.—Small apple corer or vegetable peeling knife used to remove eyes and diseased spots from potatoes. There is a blade at the side, and if a mechanical peeler is not available knives of this description are better for peeling than ordinary paring knives.

water for several hours. The water in the pans was changed until the last wash waters were practically free of starch.

The frying pan and oil were weighed

before and after the chips were cooked, to determine just how much oil was used in making a given weight of chips. A thermometer was hung in the frying pan, the bulb being covered with oil, in order that uniform temperatures might be secured for each experiment. When the oil reached 210° C. (410° F.) the thermometer was removed to another pan of hot oil, the inner basket containing the raw sliced potatoes lowered into the hot fat (fig. 6), and the slices stirred constantly with a long-handled spoon. The slices were not dried, but as much of the water as possible was removed by shaking before lowering them into the hot fat. When the water on the potatoes had boiled away and the slices were crisp and golden brown, the frying basket was raised, the excess oil drained off, and the chips emptied on brown paper to dry (fig. 7). They were later weighed (fig. 8), sprinkled lightly with salt, and scored by the three judges.

HANDLING THE FAT IN MAKING CHIPS.

If the sliced potatoes are put into oil which is at a low temperature, they take a long time to fry and absorb so much grease that they are both soggy and unpalatable. Moreover, the more grease consumed in frying, the greater the expense of the product. The aim of the hot-water bath in Miss Farmer's⁴ recipe was to coagulate the protein in the potatoes, thus searing the surface and making it impossible for much grease to soak in. The same result may be attained by heating the oil to a point just below smoking before the slices are put in. The higher the temperature that can be maintained, the sooner the surface of the potato will be crusted over and the less oil will penetrate. The water on the raw sliced potatoes and the temperature of the inner frying basket itself will lower the initial temperature of the

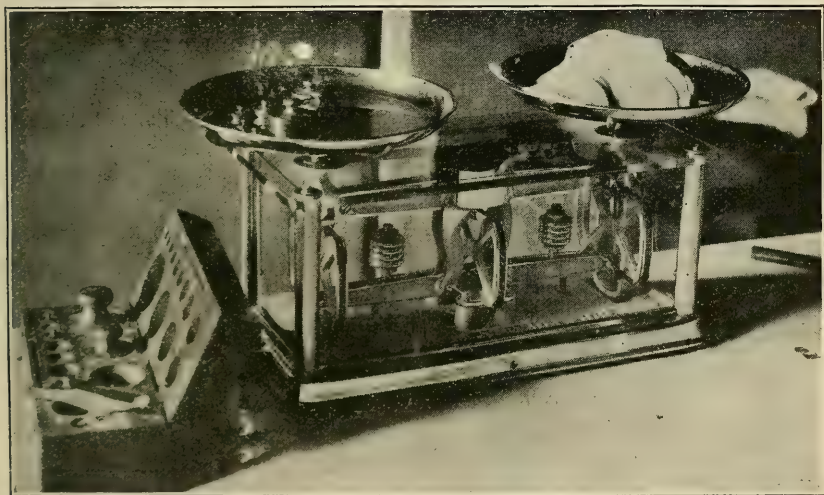


FIG. 4.—Weighing the slices of potatoes to determine the total loss in peeling and slicing.

oil, and it will take several minutes for the water to boil away and the fat to regain the heat it lost. Fats do not "boil." It is the water in the oil that makes it bubble when heated, and until this has been changed to steam and evaporated the temperature of the fat can not be raised much above 100° C. (212° F.). The hotter the initial temperature of the oil, the more quickly the water will be boiled away. As the water evaporates, the oil becomes still and the temperature increases rapidly. It should be reheated after each batch of chips is removed. The only certain laboratory method of determining the temperature of the fat is to suspend a thermometer in the center of the pan.

⁴ Farmer, Fannie Merritt. Op. cit.

Oil can not be used indefinitely without being renewed. After prolonged use of the oil the chips do not brown well and take too long to cook. Much foreign matter has been absorbed by the oil, which can not be removed by the most careful straining. It should be thrown away or used for soap grease. The common practice in potato-chip factories is to replace what is used up in the cooking process by adding fresh oil. This, however, should not be continued indefinitely, entirely fresh oil being required at least every few days. The most successful potato-chip factory which was visited makes a practice of renewing the oil every second or third day. The small particles of potato are skimmed out after every batch of chips is removed and all the oil carefully filtered each night after the close of business. New oil is added as needed during the day, and every sec-



FIG. 5.—Soaking the different lots of potatoes in pans of cold water preparatory to frying into chips. The last lot is still under the faucet of running water.

ond or third night the contents of the kettles are emptied and sold for soap grease. The result is a high-quality potato chip that will keep sweet for weeks. Some manufacturers make no effort to renew their oil entirely, simply adding fresh oil as needed. As a result the oil is never entirely sweet; and the old, worn-out oil which is always present affects the ease of cooking, the flavor, and the keeping quality of the chips.

In the refined cottonseed oil sold for cooking purposes there is remarkably little of the foreign matter from which the oil is expressed. Small particles of such foreign matter act as ferments if left in the oil and set free fatty acids which make the oil turn rancid and lower its smoking point. Chips can be cooked at a higher temperature in oil that is free from such impurities than in oil that has not been as highly refined. The small particles of fried potato or of the plant from which the oil is expressed burn and smoke at a comparatively low temperature and impart a scorched flavor to the oil, which is

transmitted to the chips. Hence the importance of buying high-grade oil and of carefully skimming out little particles of potatoes after each batch of chips is removed.

EQUIPMENT.

The mechanical peelers have been found very satisfactory as time, labor, and food savers. Of course, in the average household vegetables are not prepared in quantities large enough to make necessary the purchase of such equipment, but in restaurants, hotels, or large establishments they are found very serviceable. In potato-chip fac-

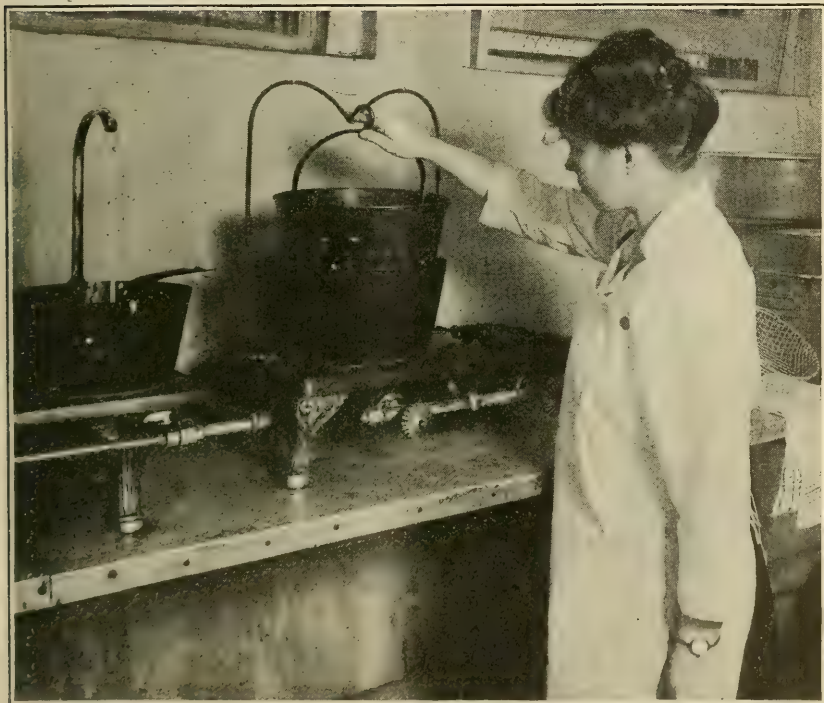


FIG. 6.—Lowering the inner basket full of raw sliced potatoes into the hot oil. The thermometer is now hung in the kettle at the left.

ories they are indispensable, and every chip factory has one or more large power machines. Figure 9 shows the small hand-power peeler which was used in the potato-chip experiments. Six or eight potatoes were peeled simultaneously. The loss in paring was less than by ordinary hand peeling, for the sharp edges of the carborundum lining nicked off the skin without cutting deeply into the flesh. The loss was least, of course, when the potatoes were smooth and regular, as the abrasion tended to wear down knobs and irregularities and leave the potatoes round or oval-oblong in shape. Deep eyes or bad spots had to be removed by hand, however. One of the small

apple corers and vegetable peeling knives retailing at 10 or 15 cents (figs. 2 and 3) was used for this purpose. In potato-chip factories a number of women or girls are employed to go over the potatoes as they are emptied from the peeler to cut out the eyes and imperfect places.

Some form of vegetable slicer is essential, as it is impossible to slice the potatoes thinly enough and evenly enough by hand. Satisfactory slicers may be obtained, either turned by hand power or motor driven. A small hand-power slicer used in 1914-15 did not prove satisfactory for laboratory tests, for the slices were thicker at



FIG. 7.—Draining the excess oil from the potato chips by spreading them on brown paper.

one side than the other, because of an imperfection in the casting of the knives. As it was necessary to secure uniformly even slices for experimental work, a larger slicer, also hand driven, was obtained at the beginning of the 1915-16 season (fig. 10). A number of large power-driven mechanical slicers, suitable for use in factories, are on the market.

When making chips at home the slices may be soaked in any kind of pans that are available. In factories they are generally soaked in tubs with fresh water fed in through rubber hose or in big tanks especially built for the purpose with fresh water flowing in at one end and an outlet pipe at the other end to carry off the wash water and starch. When working with large quantities it is generally found worth while to salvage the potato starch deposited by this wash water and by the waste from the potato peeler.

The best vessel in which to fry the chips is one that is deep rather than wide, with an inner perforated basket in which the chips can be lowered and raised. Steel friers in two parts, which are suitable for frying chips, croquettes, chicken, etc., can be obtained at hardware stores. Practically every family has some kettle suitable for deep-fat frying, and if necessary the inner basket can be improvised from steel wire. These frying pans should be of iron or steel, which is not affected by the highest cooking temperature. It is not safe to use tin or enamel-ware pans, which melt or chip off when very hot. Most potato-chip factories have large frying kettles built to suit their particular requirements, sometimes round, sometimes oblong in shape, and with special heating equipment for either gas or coal. Generally the kettles are built in one piece with the stoves. In some cases

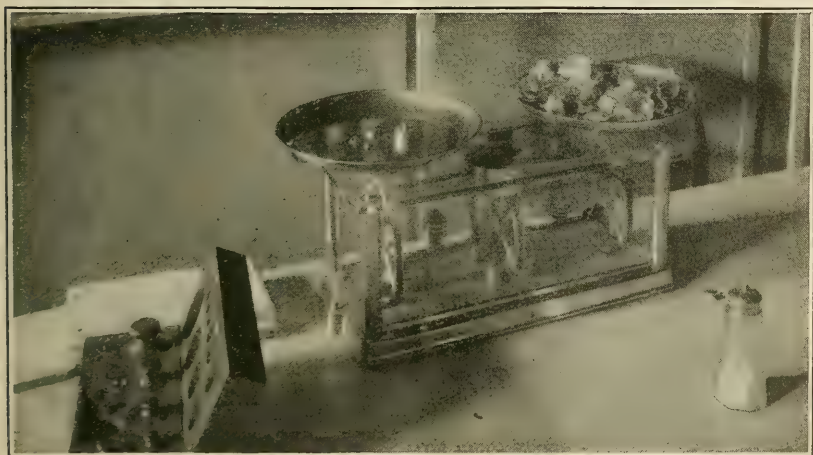


FIG. 8.—Weighing the chips, the last step before they are salted and judged.

inclined boards at one end on which the chips are emptied as skimmed out of the oil serve as drains to carry the surplus oil back into the tank or kettle. The sliced potatoes are lowered into the oil in heavy wire baskets made to fit the shape of the kettles. Sometimes, instead of frying baskets being used, the raw slices are emptied directly into the oil and the chips removed with perforated scoops or long-handled wire skimmers.

SELECTING POTATOES FOR CHIPS.

Not every potato will make a good chip, and the excellence of the finished product, here as elsewhere, depends on the materials used and the care exercised in their preparation. The following requirements should be observed when selecting potatoes for chips:

Use mature potatoes. New potatoes in the spring or early summer do not make good chips. They should not be used before the skin sets. Manu-

facturers who use potatoes in large quantities are agreed that the old stock is preferable for chips to the immature potatoes of the spring or early summer.

Use potatoes high in starch. A waxy or soggy potato does not make good chips. Select a variety that is known to be mealy when baked or boiled. The raw flesh should be firm and crisp when sliced with a sharp knife.

Use large or medium-sized round, smooth potatoes with shallow eyes. The size and shape do not affect the cooking quality, but they do influence the quantity and appearance of the chips. Round potatoes are better than long ones, as there is less waste in peeling, especially if a vegetable peeler is used. Deep eyes are objectionable, because of the difficulty of paring and the waste involved and because they make ragged-looking slices.



FIG. 9.—Small hand-power vegetable peeler. The potatoes are thrown by centrifugal motion against the carborundum lining, which nicks off the skin in small bits. Fresh water drips through the perforated pan at the top, carrying away the skins through the rubber waste pipe at the base.

Care should be taken not to cook too many chips at once. The fat should be deep enough to cover the slices completely, and allow them to lie flat and be crusted over quickly. If the kettle is too full, the water on the raw slices will bubble high and splash over the sides of the pan or vat. They cook quickly, the time required varying with the size of the kettle and the quantity of oil and potatoes used. Three to five minutes is a good average. If

they take longer something is wrong; either the oil is not hot enough or the quantity of potatoes cooked is too great in proportion.

CAUSES OF FAILURE IN MAKING CHIPS.

The troubles of commercial manufacturers are generally due to one or more of the three following causes: (1) The use of a potato

variety not adapted for making into chips. (2) Improper washing of the sliced potatoes. Some factories do not recognize the importance of removing a maximum amount of starch. The result is a tough instead of a crisp chip. (3) Using the oil at too low a temperature and not renewing it frequently enough. When the oil is not hot enough the chips absorb too much grease, and when it is too old they have a burned or spoiled flavor and turn rancid quickly. Chips fried in fresh sweet oil should keep sweet for weeks unless

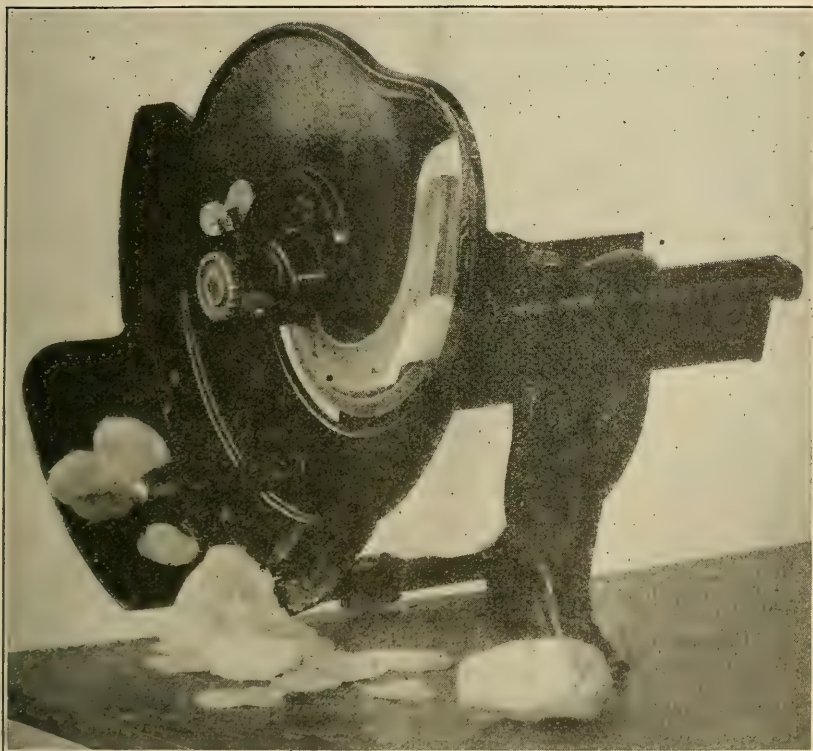


FIG. 10.—Hand-power vegetable slicer purchased at the beginning of the 1916 season.

subjected to very high temperatures and should permit long-distance shipment.

SCORE CARD USED IN THESE TESTS.

The form of the score card used in keeping a record of each lot of potato chips is shown here. The markings were all numerical, with the exception of the two subdivisions, "shape" and "desirability," under "tubers." Shape might be designated either by a descriptive term, such as flat, round, oval, etc., or by a pencil sketch. Symbolic markings, with the following divisions—very good, good, medium, poor, and very poor—indicated the desirability of each lot, as shown

by their general appearance and shape. The different weights of the tubers were recorded in grams. While the standard temperature of the fat was 210° C. and endeavor was made to raise the temperature of the oil to that point for each test, there were variations, especially when different frying media were being experimented with. Provision was made in one column, therefore, for keeping a record of the temperature at which each lot was cooked.

SCORE CARD USED IN POTATO-CHIP TESTS.

Variety..... Accession No.....
 Grown at..... Picked..... Shipped.....
 Stored..... in..... at..... Out.....
 Test..... Potato chips. Frying medium..... Date.....

Tubers.			Weight.				Temperature of fat (° F.).	Cooking time (minutes).	Ease of cooking (10).	Appearance (5).	Crispness (5).	Flavor (10).	Total score (30).
Number.	Shape.	Desirability.	Un-peeled.	Peeled.	Sliced raw.	Chips.							
.....													
.....													
.....													

Method.....

Remarks.....

Ease of cooking was given 10 points out of a possible total score of 30, the rating being necessarily left to the judgment of the person who conducted the tests. It was based on the general behavior of the potatoes in the hot fat, the length of time a lot of given quantity took to fry, and the uniformity with which the slices colored and became crisp. The other three subdivisions of the score were marked by the three judges who tested all the potatoes. Under "Appearance" (5 points) the ideal was a clear, yellowish brown, flat chip. "Crispness" (5 points) was marked high when the chips were dry and crisp, greasiness or unevenness in cooking lowering the score. Flavor (5 points) was, of course, largely a matter of individual preference. With fresh bland oil there is no heavy, greasy flavor to obscure the variations in the different potatoes.

COMPARATIVE ADAPTABILITY OF VARIETIES FOR MAKING CHIPS.

The total scores given the different seedlings from which potato chips were made during 1915, 1916, and 1917, were averaged when several tests were made. S 22723 ranked highest, with an average

score of 28.4 for two seasons' tests, 27.2 in 1916 and 29.7 in 1917. In a 1-season test there was only one seedling whose total score exceeded 29.7, and that was S 38595 with 29.8, a difference so slight as to be negligible. Many of the seedlings graded 29.0 or more, however. The lowest average score was 20.9, given to S 7322, and the lowest single score was 12.3, given to S 1449. In this connection, it should be borne in mind that those potatoes which were evidently unsuited for chips were not subjected to this test.

TABLE 1.—*Comparison of the adaptability for chips of standard varieties of potatoes tested in 1915, 1916, and 1917.*

[Based on a score of 30 for perfect.]

Group and variety.	Score for making chips.				Group and variety.	Score for making chips.			
	1915	1916	1917	Average.		1915	1916	1917	Average.
Irish Cobbler:					Rural:				
Irish Cobbler.....	24.1	23.5	27.2	24.9	Rural New Yorker..	23.1	27.3		25.2
Early Beauty.....			28.8		Nonblight.....			26.3	
Early Victor.....			28.2		Pan American.....			28.6	
Flourball.....			29.5		Sensation.....			26.3	
First Early.....			29.2		Sir Walter Raleigh..			25.8	
New Early Standard.			27.9		Todd's Wonder.....			24.3	
Triumph:					Russet Rural.....			27.2	
Triumph.....	19.2		25.6	22.4	Pearl:				
White Triumph.....			26.5		Pearl.....	22.2		23.2	22.7
Wood's Earliest.....			26.0		Dearborn.....			26.7	
Early Michigan:					Peoples.....		25.5		
Early Michigan.....			28.0		Blue Victor.....			23.8	
Early Albion.....			27.1		Peachblow:				
Early Harvest.....			28.6		White Peachblow.....		25.3	26.1	25.7
Extra Early Sunlight			28.4		McCormick.....	20.3			
Dewdrop.....			25.5		White McCormick.....		24.9		
Ehnola.....			28.3		Up-to-Date:				
Early Rose:					Factor.....	27.5			
Early Rose.....	24.1				Up-to-Date.....	25.8	25.1	26.3	25.7
Early Walters.....			24.2		Bull Moose.....			26.8	
Northern King.....	28.2	27.6	27.9		Gold Standard.....			26.1	
Woodbury's White					Moreton.....			23.1	
Rose.....			27.3		Miscellaneous:				
Early Manistee.....	26.4	27.0	26.7		British Queen.....			29.5	
Spaulding No. 4					Casseker Salathorn-				
(Rose No. 4).....	18.7				chen.....		23.0		
Early Ohio:					Chio.....			24.8	
Early Ohio.....	18.8	25.4	27.1	23.7	Country Gentleman..			28.7	
Acme.....			26.7		Dalmeny Challenge..	24.0	27.0	25.5	
Early Dix.....			27.5		Eldorado.....		25.6	26.7	26.1
Hebron:					Garnet Chili.....	25.5		26.1	25.8
New White Hebron..			27.5		Hamburgen Eier.....		25.1	26.8	25.9
Burbank X Early					Harvest King.....			28.7	
Ohio.....			26.6		Jones Pink Eyed				
Burbank:					Seedling.....		19.1		
Viking No. 1.....			27.5		Keeper.....			26.0	
Netted Gem.....	27.8	23.2	25.5		McIntyre.....		25.6	23.6	24.6
Green Mountain:					Maggie Murphy.....			25.2	
Green Mountain.....	24.2	26.6	29.0	26.6	New Era.....			27.2	
Green Mountain, Jr..			26.5		Pehuena.....		23.7		
Carman No. 1.....			28.3		Prof. Maerker.....		20.0	21.3	20.6
Gold Coin.....			28.6		Perkin's Seedling.....			25.4	
McKinley.....			26.7		Rural Blush.....		20.3	24.7	22.5
Uncle Sam.....			27.4		Saxony.....			24.7	
Wee McGregor.....			27.3		Sport of Garnet Chili			25.1	
McGowan Wonder..			29.5		Switze.....		7.0	17.8	12.4
Longfellow.....			25.5		Wohltmann.....		10.1	24.2	17.1
					Vitality.....			24.0	

Table 1 summarizes the scores of those standard varieties of potatoes which were made into chips. The Green Mountain received the

highest average score, 26.6, based on three years' tests. In the single season's scores there were three varieties that were tied for highest place, Flourball, American Wonder, and British Queen, all scoring 29.5 in 1917. The lowest average score, 12.4, was given to Switez, one of the German starch varieties. This variety was not adapted for chip making and was merely tried to see how it would behave. The same may be said of the potato receiving the second lowest score, 17.1, Wohltmann, another German variety. The lowest 1-year score was given to Switez in 1916 also.

LOSS IN PEELING AND QUANTITY OF CHIPS OBTAINED.

Table 2 gives a 3-year average of the loss in peeling and the quantity of chips made from all lots, with detailed figures for a few of the better known commercial varieties. The average waste in peeling all the potatoes handled during 1915, 1916, and 1917, a total weight of 233,492 grams, averaged 12.47 per cent, and the quantity of chips obtained averaged 29.85 per cent of the weight before peeling. In 1915 the average loss for all lots was 13.16 per cent and the average weight of the chips produced was 27.43 per cent of the original weight of potatoes. In 1916 the loss through peeling alone averaged 14.33 per cent; through both peeling and slicing, 17.48 per cent; and the quantity of chips produced averaged 30.22 per cent of the original weight. In 1917 the loss through peeling alone averaged 11.67 per cent; through peeling and slicing, 16.36 per cent; and the chips weighed 30.18 per cent of the original weight of potatoes. The 3-year average was therefore reduced by the 1915 figures, both the 1916 and the 1917 averages being slightly over 30 per cent. Commercial men figure on getting between 15 and 27 per cent of chips from each barrel or sack of potatoes. Their percentages of waste in peeling are higher than the 12.47 per cent given here, for more careful methods were employed in the laboratory than would be possible in a large factory. Langworthy⁵ estimates the average waste in peeling potatoes to be 20 per cent, and with careless methods it may go even higher.

The lowest possible percentage of waste in peeling may depend upon a number of factors, such as variety, place where grown, and condition of the tubers (i. e., firmness, freedom from injury, decay, sprouts, etc.). The shape of the variety is one of the chief determining factors, for when the tuber is irregular, knobby, with deep or numerous eyes, it is practically impossible to prevent paring deeply. The skin itself varies slightly, being thicker on certain varieties, especially those with rough or netted exteriors. The influence of different soil types and environmental conditions sometimes causes a greater vari-

⁵ Langworthy, C. F. Potatoes, sweet potatoes, and other starchy roots as food. U. S. Dept. Agr. Bul. 468, 29 p., 7 fig. 1917.

ation in shape, general appearance, and quality between specimens of the same variety grown in different parts of the country than is found in different varieties produced in the same locality. The condition of the tubers at the time of peeling also influences the percentage of waste. The value of careful handling, though less popularly appreciated in the case of potatoes than with most perishable crops, has been clearly demonstrated. Cuts and bruises caused by careless methods of harvesting and handling are followed by decay in storage and make necessary much deeper paring into the flesh. Old potatoes that have softened and begun to sprout are much more difficult to peel economically. When the flesh is hard and firm the knife can shave off a thinner portion of crisp flesh than after some of the water has evaporated and some of the starch has been converted into sugar, leaving the flesh with a rubbery texture.

TABLE 2.—*Comparison of certain standard varieties of potatoes, showing the loss in peeling and slicing and the quantity of chips produced, Arlington Experimental Farm, 1915, 1916, and 1917.*

Varieties compared.	Year.	Weight unpeeled (grams).	Average loss in weight (per cent).		Weight of chips per kilogram of potatoes (grams).		
			By peeling.	By peeling and slicing	Un-peeled.	Peeled.	Sliced raw.
Green Mountain.....	{ 1915	1,000	12.2	-----	272	309.8	-----
	{ 1916	4,417	16.8	21.46	289.1	347.5	368.2
	{ 1917	6,377	12.70	17.09	305	362.2	376.5
	2-year average, 1916 and 1917.....	10,794	14.37	18.88	307.1	358.6	378.6
	3-year average, 1915, 1916 and 1917.....	11,794	14.10	-----	304.1	354.4	-----
Irish Cobbler.....	{ 1915	2,002	13.49	-----	268.2	305.4	-----
	{ 1916	2,192	19.84	21.99	264.6	330.1	339.2
	{ 1917	396	19.95	22.72	275.2	343.8	356.2
	2-year average, 1916 and 1917.....	2,588	19.86	22.10	266.2	332.2	341.2
	3-year average, 1915, 1916, and 1917.....	4,590	17.08	-----	265.3	320.0	-----
Rural New Yorker.....	{ 1915	2,000	14.35	-----	218.0	254.2	-----
	{ 1916	2,581	9.26	12.55	275.1	303.1	314.5
	2-year average, 1915 and 1916.....	4,581	11.43	-----	250.1	282.4	-----
Early Ohio.....	{ 1915	1,000	11.8	-----	321	363.9	-----
	{ 1916	2,323	10.8	13.43	299.2	335.4	345.6
	{ 1917	285	12.98	17.19	291.2	334.7	351.7
	2-year average, 1916 and 1917.....	2,608	11.04	13.84	298.3	335.3	346.2
	3-year average, 1915, 1916 and 1917.....	3,608	11.25	-----	304.6	343.2	-----
Up-to-Date.....	{ 1915	1,005	9.25	-----	306.5	337.7	-----
	{ 1916	2,008	5.8	8.87	325.7	345.9	357.4
	{ 1917	395	6.83	11.39	308.9	331.5	347.6
	2-year average, 1916 and 1917.....	2,403	5.99	9.23	304.1	321.3	355.8
	3-year average, 1915, 1916 and 1917.....	3,408	6.95	-----	318.0	340.9	-----
Peachblow.....	{ 1916	2,667	8.73	11.18	329.6	361.1	371.08
	{ 1917	374	7.22	11.50	334.2	360.2	377.6
2-year average, 1916 and 1917.....		3,041	8.54	11.21	330.1	361.0	371.8

TABLE 2.—*Comparison of certain standard varieties of potatoes, showing the loss in peeling and slicing and the quantity of chips produced, Arlington Experimental Farm, 1915, 1916, and 1917—Continued.*

Varieties compared.	Year.	Weight unpeeled (grams).	Average loss in weight (per cent).		Weight of chips per kilogram of potatoes (grams).		
			By peeling.	By peeling and slicing.	Un-peeled.	Peeled.	Sliced raw.
Netted Gem (Colo.).....	1916	1,586	9.98	12.42	319.0	354.36	365.4
Netted Gem (Me.).....	1917	264	12.5	16.66	306.8	350.6	368.2
2-year average, 1916 and 1917.....		1,850	10.32	13.02	317.2	353.8	364.8
Garnet Chili.....	{ 1915	1,000	14.8	-----	277	325.1	-----
	{ 1917	492	13.6	17.2	315	364.7	380.8
2-year average, 1915 and 1917.....		1,492	14.41	-----	289.6	338.2	-----
Pearl.....	{ 1915	1,000	12.5	-----	234.0	267.4	-----
	{ 1917	373	16.08	22.0	262.7	313.1	336.8
2-year average, 1915 and 1917.....		1,373	13.47	-----	241.8	279.4	-----
Bliss Triumph.....	{ 1915	1,000	14.0	-----	197.0	229.1	-----
	{ 1917	370	14.32	18.9	297.3	347.0	366.7
2-year average, 1915 and 1917.....		1,370	14.08	-----	224.0	260.8	-----
Early Manistee.....	{ 1916	994	18.41	20.32	308.9	378.6	387.6
	{ 1917	321	7.16	9.97	314.6	338.9	349.5
2-year average, 1916 and 1917.....		1,315	15.66	17.79	310.2	367.9	377.4
Eldorado.....	{ 1916	1,000	14.2	17.5	319.0	371.8	386.7
	{ 1917	210	10.00	16.19	304.7	338.6	363.6
2-year average, 1916 and 1917.....		1,210	13.47	19.96	316.5	365.8	382.6
Rural Blush.....	{ 1916	432	33.8	36.34	240.7	363.7	378.2
	{ 1917	297	12.45	16.83	285.0	353.8	372.4
2-year average, 1916 and 1917.....		729	25.10	28.39	268.8	358.8	375.3
McIntyre.....	{ 1916	387	16.79	18.34	320.5	385.1	392.4
	{ 1917	298	16.10	21.81	268.4	320.0	343.3
2-year average, 1916 and 1917.....		685	16.49	19.85	297.8	356.6	378.8
Hamburger Eier.....	{ 1916	196	16.83	20.41	295.9	355.8	371.8
	{ 1917	252	13.89	22.62	277.8	322.5	359.0
2-year average, 1916 and 1917.....		448	15.17	21.65	285.7	336.8	364.3
1-year average of all seedlings and varieties.....	{ 1915	24,695	13.16	-----	274.3	310.8	-----
	{ 1916	130,764	14.33	17.48	502.2	349.2	363.1
	{ 1917	78,033	11.67	16.36	301.7	341.9	361.6
2-year average, 1916 and 1917.....		208,797	12.39	16.56	301.9	343.4	361.2
3-year average, 1915, 1916, and 1917.....		233,492	12.47	-----	298.5	341.0	-----

When the potatoes are sound and in good condition most of the 12.47 per cent waste in peeling is composed of flesh around the eyes. If the eyes are deep it is not possible to gouge them out with a knife as carefully as the skin is removed by the peeler. This loss is less important than an equally deep peeling elsewhere, however, for the internal medulla extends a branch to each eye, lessening the proportion of dry matter to water and reducing accordingly the food value of the flesh. East ⁶ has shown that the quality of the potato varies

⁶ East, Edward M. A study of the factors influencing the improvement of the potato. Ill. Agr. Exp. Sta. Bul. 127, p. 375-456, 10 fig. Bibliography, p. 450-456. 1908.

inversely with the number of eyes, and that there is great variation within the variety.

Table 3 shows that approximately half a pound of oil was used for every pound of chips produced, or, to be more exact, 0.451 pound in 1916 and 0.434 pound in 1917. This was slightly less than the estimates furnished by two manufacturers of potato chips. Not all of this oil went into the chips, however, a great deal being lost through spattering over the pan, in draining the chips, and in straining the oil.

TABLE 3.—*Ratio of cottonseed oil required for making potato chips, tests of 1916 and 1917.*

Year.	Number of tests.	Average weight (grams).		Ratio.	
		Oil used.	Chips made.	Oil.	Chips.
1916.....	47	369	818	0.451	1
1917.....	33	312.45	718.66	.434	1

SUMMARY.

Potatoes are a universal article of diet, and their home manufacture into potato chips is entirely feasible. High-grade cottonseed oil heated to approximately 210° C. (400° F.) is the best fat in which to fry them. Vegetable oils or compounds are more satisfactory than animal fats, and liquids are somewhat preferable to the semiplastic compounds. No fat with a smoking point of less than 220° C. (428° F.) is satisfactory. The oil should be entirely renewed every second or third day when chips are manufactured in commercial quantities.

Mechanical peelers are necessary for commercial production and of great assistance in home manufacture. Vegetable slicers are essential for uniform results, as it is impossible to cut potatoes thinly and evenly enough by hand.

The best vessel in which to fry the chips is one that is deep rather than wide, made of iron or steel, with an inner perforated basket in which the chips can be lowered and raised.

Use mature potatoes, high in starch. Large or medium-sized, round potatoes with shallow eyes are preferable. The slices should be thoroughly washed in cold water and a maximum of starch removed.

In the experimental tests of the Bureau of Plant Industry, potato chips were scored on a basis of 30 points, distributed as follows: Ease of cooking, 10; appearance, 5; crispness, 5; flavor, 10.

The average waste in peeling all potatoes handled during 1915, 1916, and 1917 was 12.47 per cent, and the quantity of chips produced averaged 29.85 per cent of the weight before peeling. Commercial men figure on getting between 15 and 27 per cent of chips from each barrel or sack of potatoes.

Approximately half a pound of oil was used for every pound of chips produced.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1056

Contribution from the Bureau of Markets and
Crop Estimates
H. C. TAYLOR, Chief



Washington, D. C.



April 5, 1922

MARKETING COTTON SEED FOR PLANTING PURPOSES.

By J. E. BARR, *Investigator in Marketing Seeds.*

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The area devoted to the production of cotton in the United States annually averages 35,000,000 acres. To plant this acreage requires approximately 500,000 tons or a billion pounds of seed, about one-tenth of the average total annual production. It has been estimated that normally 30 per cent of this total planting requirement is obtained by farmers from commercial sources, 70 per cent being produced on the farm where used.

The number of persons and concerns dealing in cotton seed for planting purposes and the total volume of their annual business have increased steadily. However, comparatively little effort has been made to improve the commercial and agricultural value of their stock. It is true that a limited number of growers and dealers are endeavoring to develop either new varieties or improved strains of standard varieties; but the possibilities of enhancing the commercial and agricultural value of cotton seed by better methods of preparing, storing, and marketing have been overlooked or neglected. As a

result the average commercial cotton seed of to-day used for planting does not measure up to a high standard.

The seed dealer's place in the channels of trade is justified largely by services rendered in improving the quality of his product. If his stock is no improvement over the average farmer's stock, farmers will continue to be more or less skeptical regarding it, on the basis of the increased prices usually asked. On the other hand, if commercial cotton seed for planting possesses superior qualities and honest efforts are made to prove its superiority, skepticism regarding its true value will not long remain in the minds of farmers. There is rarely, if ever, an oversupply of really superior seed and no effort should be spared by commercial agencies and others to make the term "planting cotton seed" stand for something of infinitely greater agricultural value than the average cotton seed now used for planting, and thereby to render a distinct service to the cotton-growing industry.

The ideal planting cotton seed may be described as seed selected from cotton that is true to type and pure of variety; well matured; free from disease and insects or insect injury; delinted; recleaned and graded; and with a minimum germination of 88 per cent. By pointing out some of the fundamental points in selecting, improved methods of preparing and storing, and ways of overcoming or eliminating some of the existing unfair and unscrupulous practices in selling planting cotton seed, all classes of dealers may be aided in making their product approach more closely the ideal and farmers may be guided in determining its intrinsic value when making purchases.

SOURCES OF SUPPLY.

The percentage of the total planting requirement of cotton seed that is sold commercially varies from year to year and is influenced largely by one or more of the following factors: (1) Extent of boll weevil and pink boll worm injury and expansion of the area infested, which creates an abnormal demand for seed of early maturing varieties grown in noninfested territory; (2) excessive and continued rains during the harvest period, adversely affecting the germination; (3) unfavorable weather conditions during the planting season, necessitating more or less replanting; (4) general prosperity of the cotton farmer; and (5) spasmodic changes in the acreage. The percentage obtained by farmers from commercial sources also varies greatly in the several cotton-producing States, as shown in Table 1:

TABLE 1.—*Sources from which farmers obtain planting cotton seed and estimated normal percentage and quantity obtained from each source.*

State.	Total quantity required for planting.	Produced on farm where used.		Obtained from other farmers.		Obtained from dealers.	
	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.
Virginia.....	1,755,000	47	825,000	16	281,000	37	649,000
North Carolina.....	54,645,000	69	37,707,000	17	9,290,000	14	7,651,000
South Carolina.....	100,695,000	80	80,556,000	13	13,090,000	7	7,049,000
Georgia.....	163,614,000	80	130,891,000	12	19,634,000	8	13,089,000
Florida.....	2,626,000	34	893,000	15	394,000	51	1,339,000
Missouri.....	4,736,000	23	1,089,000	13	616,000	64	3,031,000
Tennessee.....	29,664,000	70	20,765,000	13	3,856,000	17	5,043,000
Alabama.....	93,786,000	76	71,277,000	11	10,317,000	13	12,192,000
Mississippi.....	99,792,000	80	79,834,000	10	9,979,000	10	9,979,000
Louisiana.....	50,470,000	76	38,357,000	13	6,561,000	11	5,552,000
Texas.....	314,400,000	56	176,064,000	13	40,872,000	31	97,464,000
Oklahoma.....	66,360,000	46	30,526,000	20	13,272,000	34	22,562,000
Arkansas.....	100,170,000	70	70,119,000	23	23,039,000	7	7,012,000
Arizona.....	4,470,000	27	1,280,000	11	521,000	62	2,939,000
California.....	2,980,000	9	268,000	6	179,000	85	2,533,000
United States.....	1,090,436,000	68	740,451,000	14	151,901,000	18	198,084,000

The percentage shown as obtained direct from other farmers is considered commercial seed and is included in all references to commercial seed in this discussion. The quantities given in the table are based on the 1920 acreage and the reported average rate of seedling per acre in each State.

SELECTION OF SEED STOCKS.

The production of planting cotton seed is so closely allied with the marketing of it that a line of demarcation between the two activities is difficult to draw. The agricultural value of the finished product sold depends in a large measure on the growing crop and the stock seed from which it is produced. The stock seed should compare favorably with the "ideal." It should come direct from the originator of that particular variety, or the conditions under which it has been handled and propagated since leaving the originator's hands should conform with approved methods of growing and selecting cotton seed for planting purposes.¹ The dealer should maintain close cooperation with the grower and have direct supervision over the growing crop. To this end advance growing contracts may be advantageous. Roguing the fields one or more times prior to and during blossoming time is desirable in order to remove all barren, diseased, and off-type plants.²

The cotton from which seed is selected should be well-matured and dry when picked. Seed from the top bolls on the plants and from

¹ Distribution of Cotton Seed in 1921, U. S. Department of Agriculture Circular 151, 1920.

² Cook, O. F.: Cotton Selection on the Farm by the Characters of the Stalks, Leaves, and Bolls. Bureau of Plant Industry Circular No. 66. 1910.

cotton harvested late in the season, after frosts and storms, almost invariably is of low vitality and of poor quality for planting purposes. If a field contains a high percentage of diseased plants this fact immediately disqualifies it as a source of planting seed supply. Also, any appreciable damage by the boll weevil and pink boll worm renders cotton seed unfit for planting purposes even in infested territory, while quarantine measures prohibit the shipment and sale of cotton seed from infested areas into noninfested territory.

PREPARATION.

Cotton seed, unlike most other leading field seeds, continues to be sold and planted in a rather crude physical condition. Dealers seem to overlook the fact that commercial cotton seed of the most carefully selected and improved strains can be made of still greater value from the farmers' point of view by the use of modern machinery in ginning, delinting, and recleaning and grading. The commercial advantages of better preparation are measured by the agricultural advantages accruing to the farmer planting the better prepared seed. If it does not mean a larger net profit to the farmer by promoting more economical production or a greater yield, the increased cost is not justified. On the other hand when it is evident that a process or method of improving the physical condition of cotton seed enhances its value for planting purposes, it is incumbent on the dealer to use the process. A reduction of 100,000 tons of cotton seed in the annual seeding requirement and a saving of 30,000,000 pounds of linters, now a total waste, for industrial purposes, would result through the more thorough and uniform removal of the surplus lint and the culling out of all extraneous matter and small and lightweight inferior seed by the application of such methods as are now available.

GINNING.

The first mechanical operation affecting the appearance and physical condition of cotton seed is ginning.³ Improvements in ginning machinery during recent years enable the operator to produce much cleaner seed than formerly. Most of the sand, dirt, burs, and other foreign material is removed automatically. The most modernly equipped gin plant, however, will not turn out seed in the best condition unless a thoroughly competent operator is in charge and unless the cotton to be ginned is fully matured and dry. There are thousands of gins in the cotton belt but relatively few skilled operators who appreciate the importance of improving the physical condition

³ Taylor, Fred, Griffith, D. C., and Atkinson, C. E.: Cotton Ginning Information for Farmers, U. S. Department of Agriculture, Farmers' Bulletin 764. 1916.

and preserving the varietal purity and identity of cotton seed to be used or sold for planting purposes.

No attempt should be made to gin cotton that is "green" or that has become damp, as it is difficult to prevent the seed from such cotton from becoming "heated" in storage. An important precautionary measure which always should be kept in mind is the prevention of the admixture of varieties at the gin. Before changing from one variety to another the roll box should be emptied and, together with the flues, feeders, conveyers, bins, should be thoroughly cleaned. This factor has been discussed fully in a previous publication of the United States Department of Agriculture.⁴

DELINTING.

Delinting is one of the most important factors essential to the preparation of the ideal planting cotton seed. It is evident that any process which removes the surplus lint without impairing the germination is of prime importance in the improvement of cotton seed for planting purposes and the same interest should be manifested in delinting as in maintaining the purity of variety, trueness to type, or other factors pertaining to the cotton from which the seed is selected.

From a commercial point of view, delinting offers dealers an opportunity to improve the quality and intrinsic value of their product and to maintain the grade of it at a higher level than the average farmer's stock or what is termed "gin-run" seed.

AGRICULTURAL ADVANTAGES.

The delinting process offers decided possibilities for bettering agricultural practice. It promotes a uniform stand of plants by enabling the seed to germinate more quickly and with the aid of less moisture. In "gin-run" seed, regardless of variety or strain, there is usually a wide variation in the quantity of lint left on the individual seeds, as is shown in figure 1, *a* and *c*. When planted, the seeds with the shortest lint on them come into closer contact with the soil moisture and germinate more quickly than those containing excessive lint. The delinted seeds, containing a small, uniform quantity of very short lint or fuzz (see figure 1, *b* and *d*), germinate at practically the same time and produce a more nearly perfect stand of plants at least two or three days earlier. This is of value in growing cotton in the presence of the boll weevil because every day gained in getting the plants above the ground increases the prospects of obtaining a profitable yield. Delinting materially assists in the emergence of cotton seedlings. In germinating the seed is forced up

⁴ Saunders, D. A., and Cardon, P. V.: Custom Ginning as a Factor in Cottonseed Deterioration, U. S. Department of Agriculture, Bulletin 288. 1915.

through the soil on the cotyledons of the cotton seedlings and a closely delinted seed offers less resistance than gin-run seed. Also the united action of the young plants, resulting from the simultaneous

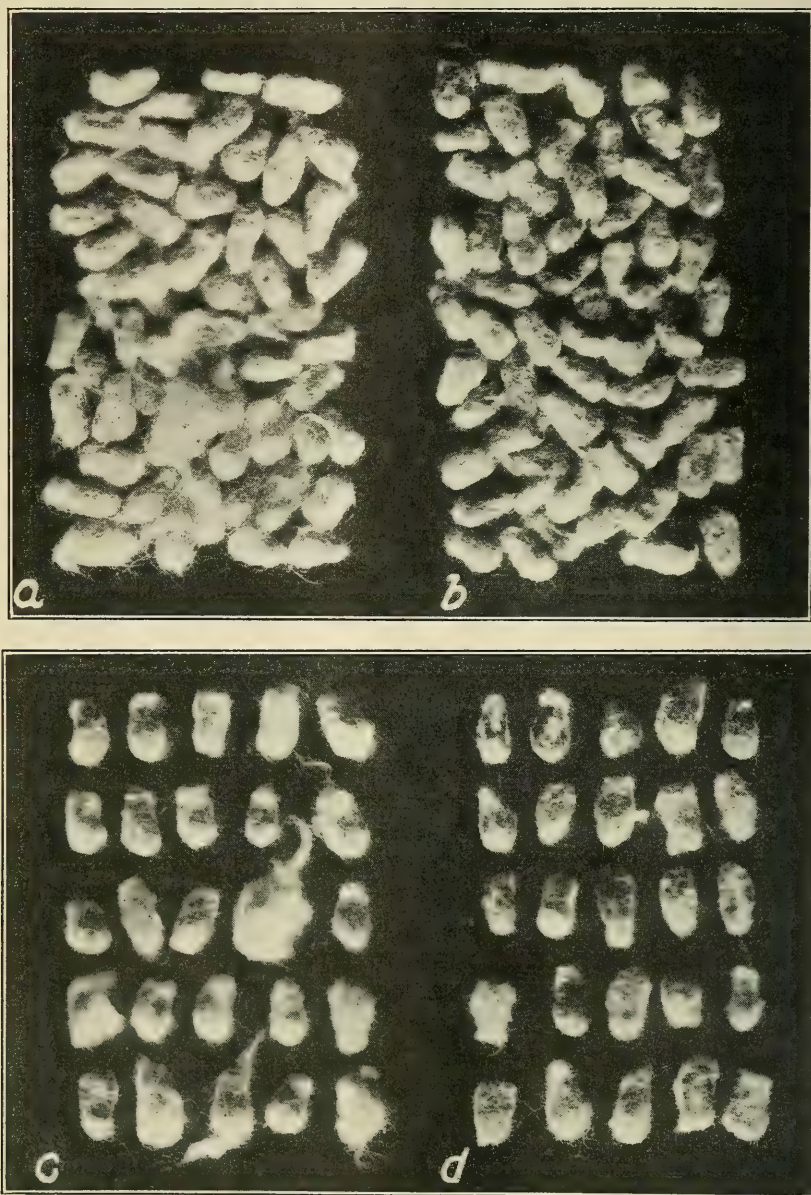


FIG. 1.—Cotton seed. *a* and *c*, Gin-run; *b* and *d*, delinted. All natural size.

germination of the delinted seeds, enables them to break through soil that has been compacted by rains with comparatively little difficulty and helps to insure a stand of plants under adverse conditions.

Delinting effects an economy in the use of cotton seed, as planting machines will distribute a smaller quantity per acre more uniformly. It will eliminate the necessity of a force feed in planting machines and facilitate the single-seed distribution and the planting of cotton seed in hills. The thin uniform stand, made possible by the use of delinted seed, also may help to simplify the culture of cotton by what is known as the single stalk method⁵ which, repeated experiments show,⁶ produces the highest yields and earliest maturity.

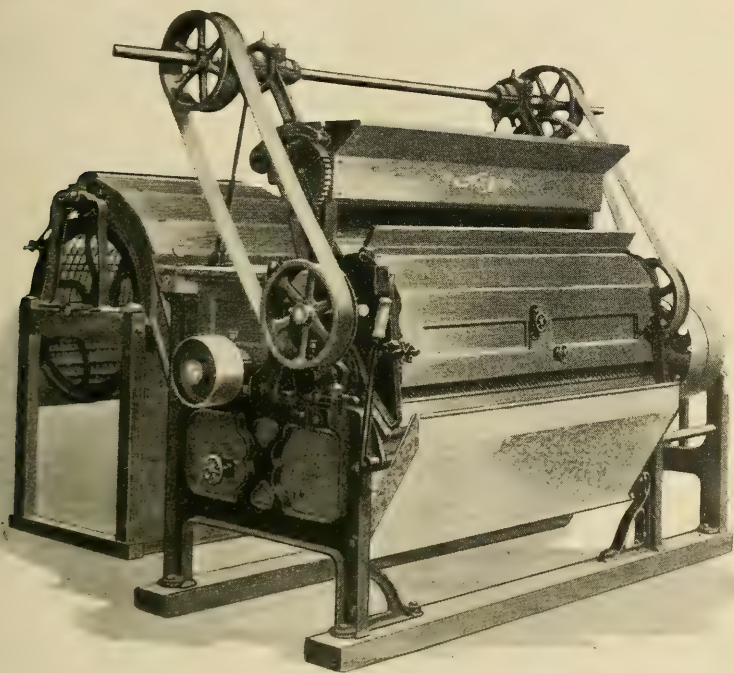


FIG. 2.—A type of machine used in delinting cotton seed.

COST OF DELINTING.

The cost of delinting, which on first thought may be expected to be excessive, is small per unit. It necessarily varies with the capacity of the plant and the quantity of seed handled or the number of days the plant is operated during a season. A plant may be installed in a dealer's warehouse and operated separately or installed and operated in connection with a ginnery. The kind of machine used is the same as that for delinting cotton seed for oil manufacture and is

⁵ Cook, O. F.: A New System of Cotton Culture and its Application, U. S. Department of Agriculture, Farmers' Bulletin 601. 1914.

⁶ Cardon, P. V.: Experiments with Single-Stalk Cotton Culture in Louisiana, Arkansas, and North Carolina, U. S. Department of Agriculture, Bulletin 526. 1918. Meade, R. M.: Single-Stalk Cotton Culture at San Antonio, U. S. Department of Agriculture, Bulletin 279. 1915.

illustrated in figure 2. Based on careful estimates submitted by manufacturers, the initial investment in machinery for a plant having a capacity of four tons per 10 hours should be about \$3,000. This amount would cover the purchase price and cost of installing the machinery, consisting of two delinting machines, press, and the necessary conveyers, elevators, and transmission equipment. The cost of the motor or other source of power is not included. Such a plant requires from 15 to 20 horsepower to operate it and a motor of this size may be purchased at around \$500, bringing the initial outlay up to \$3,500. The cost of buildings has not been considered

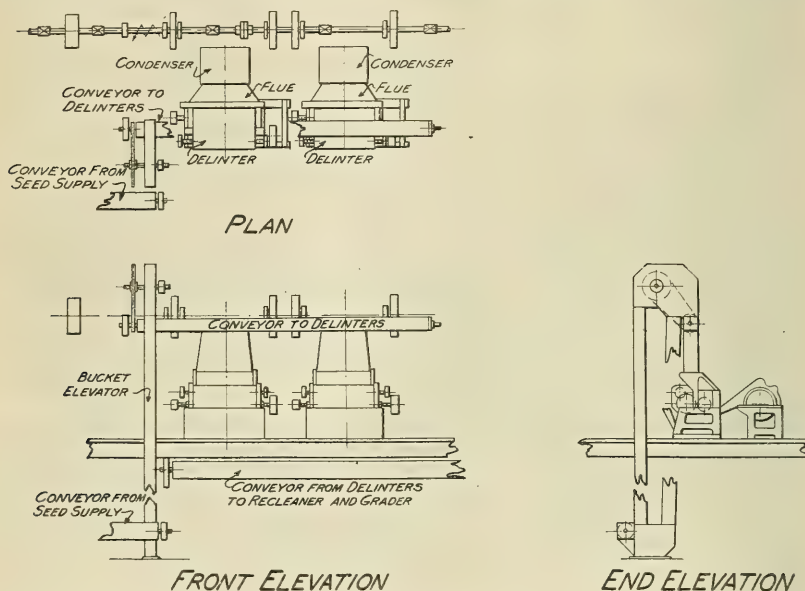


FIG. 3.—General lay-out or plan of two-unit delinting plant. Note: No attempt is made here to show the details or to suggest a fixed plan of installation. Manufacturers no doubt will be glad to cooperate with prospective buyers in working out the most economical and efficient plan of installing and operating such machinery under varied conditions and for any special requirements.

in connection with these estimates. Many dealers in planting cotton seed already have warehouses or gin buildings in which the machinery may be installed, possibly with slight alterations. The same capacity plant installed in or in connection with a ginnery costs about \$500 less because all parts of the equipment, the press for example, are not necessary. Figure 3 shows a general layout or plan of a 2-unit delinting plant.

A plant of this capacity in operation 125 days of 10 hours each in a season would delint 500 tons at a net cost of approximately \$5 per ton of delinted seed. In arriving at this figure, the cost has been distributed among the various factors as follows:

Labor cost, 2 men at \$2.50 per day, daily \$5; per ton-----	\$1.25
Power cost, daily \$6; per ton-----	1.50
Dockage per ton, linters removed, 60 pounds; dirt, trash, 90 pounds; total 150 pounds at \$40 per ton (value of the gin-run or undelinted seed)-----	3.00
Depreciation at 10 per cent, \$350; per ton-----	.70
Interest on investment at 5 per cent, \$175; per ton-----	.35
Total-----	6.80
Less value of linters removed, 60 pounds at 3½ cents-----	2.10
Net cost of delinting 1 ton of gin-run resulting in 1,850 pounds of de- linted seed-----	4.70
Net cost of delinting 100 pounds of delinted seed-----	.254
Net cost of delinting 1 ton of delinted seed-----	5.08

It should be understood that these figures are given only as an indicator of the approximate cost and of the factors which must be taken into consideration in determining the cost. The relative importance of these factors will vary from time to time. It will be noted that "dockage" appears to be the greatest item of cost. In addition to the linters removed there is always more or less loss in weight of the seed through the removal of dirt and trash by passing through the delinting machines. The total dockage must be charged for at the value of the "gin-run" or undelinted seed. In the example given this value is assumed to be \$40 per ton. To reduce this heavy charge against dockage there are 60 pounds of linters to which are assigned a market value of 3½ cents per pound, or \$2.10.

To offset further the loss of 150 pounds per ton dockage which has been charged to the cost of delinting there is the fact that the number of seed per pound increases in an equal or a greater proportion than the percentage of dockage. In this case the total dockage is 7.5 per cent, while the number of delinted seed per pound is approximately 8 per cent greater than the number of gin-run seed. The greater number of seed per pound increases the commercial value and planting capacity per unit.

A plant of one-half this capacity may be installed at \$700 to \$1,000 less. The net cost of delinting cotton seed in such a plant when operated 125 days per season is about \$7.50 per ton, or approximately 50 per cent greater than in the larger plant. The capacity of plant to be installed by a dealer will depend upon the volume of seed handled, keeping in mind the fact that 125 days is about the maximum season's length and that the output of the plant may be doubled by operating two shifts, or 20 hours.

If a plant is installed and operated in connection with a ginnery, the cost of delinting is a few cents per ton less, chiefly because of the relatively smaller investment, which reduces slightly the interest and depreciation, all other factors remaining practically the same. If the

seed as it comes from the gins contains an appreciable quantity of stones and dirt, it may be found advisable from the standpoint of economical upkeep of the delinting machines to install a cleaner through which the seed should pass before entering the delinters. A cleaning machine of this kind that will do effective work in removing stones, metallic substances, dirt, and loose lint from the seed, reducing the frequency of filing the saws, and producing a higher grade of linters, may be purchased at relatively small cost. In the absence of such a machine similar results may be obtained by equipping the delinting machines with magnets at a cost of \$30 to \$35 for each machine.

LINTERS CUT PER TON OF SEED.

One of the most important factors in delinting cotton seed for planting purposes is the quantity of linters that may be removed per ton or how close the linters may be cut without injuring the germination. The exact quantity can not be fixed because it will vary with the condition of the seed as it comes from the gin and to some extent with the different varieties. Usually more linters are obtained from seed ginned early in the season when the cotton is somewhat green than from seed ginned later or when the cotton is matured and dry. The normal rate of delinting by the cottonseed-oil mills is about 75 pounds per ton.

During the season 1916-17, because of the abnormal demand for linters for munition manufacture, an average of about 150 pounds was cut. This shows the possible extent to which the seed may be delinted, but such drastic action is liable to injure the germination. Probably 60 pounds is a safe rate of cut when the seed is intended for planting purposes. The appearance and condition of the delinted seed is the most reliable indicator as to whether the lint is being cut close enough. The operator can ascertain after a few minutes' run whether any of the seeds are being injured or whether surplus lint is being left on them, and he can easily and quickly adjust the delinters so as to cut at the proper rate.

The efficiency of this operation, as in ginning, depends to a great extent on the experience and skill of the operator and the proper care and adjustment of the machinery. The object is to cut the lint as short and to make the seed as near uniform in appearance as is possible without injury to the germ. Seeds delinted lightly and heavily, compared with gin-run, are shown in figure 4. Injury may be detected by noting whether the hulls of any of the seeds have been cut through or broken by the saws. The seeds thus cut or broken should be less than 1 per cent. (See illustration of cut and broken seeds in fig. 5.)

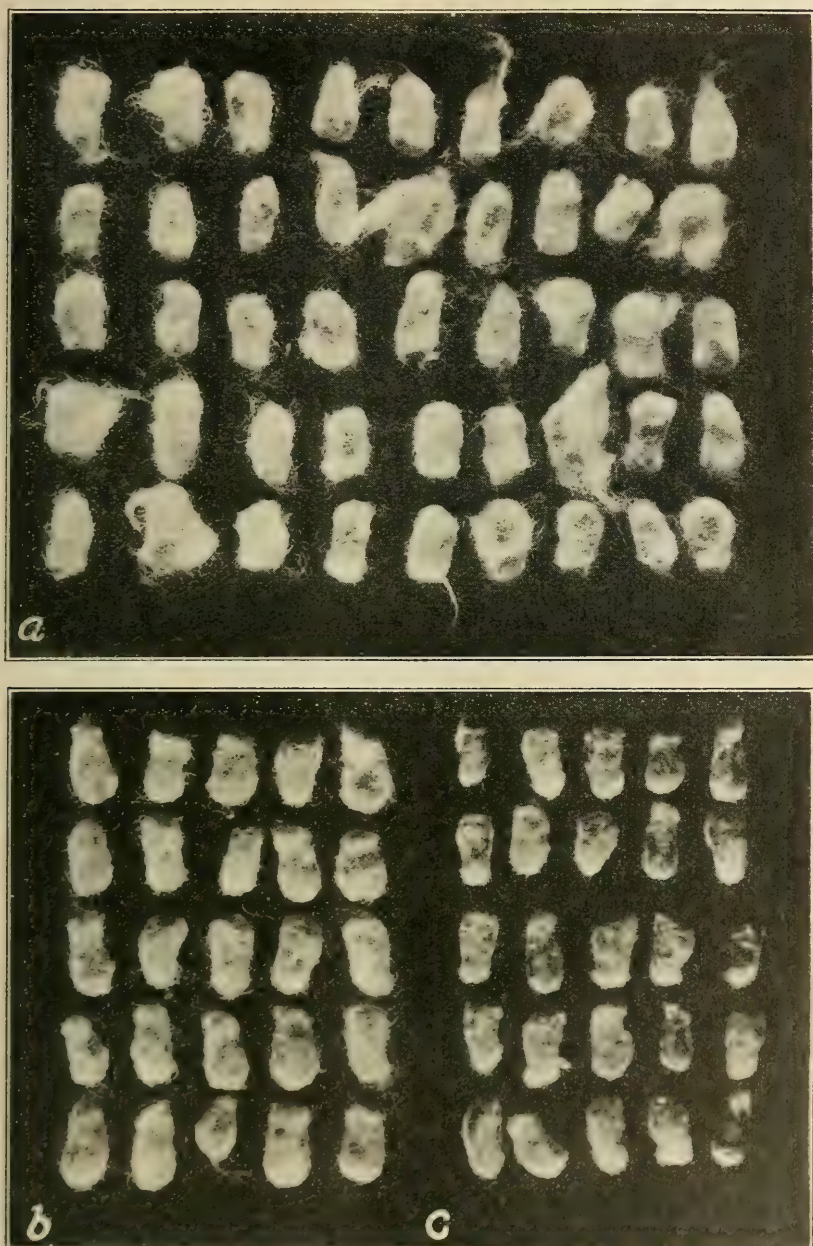


FIG. 4.—Cotton seed : *a*, Gin-run ; *b*, delinted lightly ; *c*, delinted closely, but no seeds cut or broken and very little of the black or slick hull showing. All natural size.

WEIGHT AND SIZE OF DELINTED SEED.

Delinted seed, although containing more seed per pound, is not so bulky as gin-run seed. For example, 30 pounds of gin-run seed may fill a bushel measure and contain 120,000 seeds, whereas this same lot

of seed when delinted would weigh about $27\frac{3}{4}$ pounds and measure only approximately four-fifths of a bushel. However, it would still contain the same number of seeds (120,000) and have the same or a greater planting capacity. Also it should be remembered that if 30 pounds (a bushel measure) of gin-run seed contain 120,000 seeds, 30 pounds of delinted seed contain approximately 130,000 seeds and have a proportionately greater planting capacity, although they may not fill a bushel measure. The number of seeds per pound or per bushel varies with the different varieties of cotton, some of which have much larger seeds than others, but a given number of delinted seeds, regardless of variety, weigh from 5 to 10 per cent less and are from 10 to 20 per cent less bulky than an equal number of gin-run seeds of the same variety.

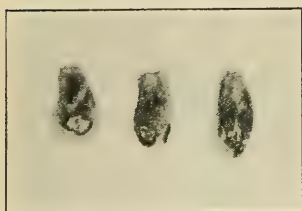


FIG. 5.—Cotton seed cut or broken by saws in delinting. Natural size.

APPEARANCE OF DELINTED SEED.

The delinted seeds have a more brownish appearance than gin-run seeds and some may be so closely delinted that the black hull shows partially as illustrated figure 6. Rarely, however, do they have the appearance of "slick seed" and there is no basis for the contention that the slick appearance of the seeds would cause farmers to be skeptical regarding the purity as to variety. Neither can delinting be construed as a cloak which might be used by unscrupulous dealers to hide inferior qualities. On the other hand, it should help indirectly to minimize the number of dealers in this class or reduce greatly the comparative volume of their business. The poorest quality of gin-run cotton seed sold for planting purposes would be improved by delinting and subsequent recleaning and grading. It is not intended that delinting should take the place of breeding, selecting, or any other phase of improving the value or productiveness of cotton seed, but that it should supplement these methods and make the most carefully bred or selected cotton seed of still greater value for planting purposes.

RECLEANING AND GRADING.

Modern and specially designed machinery is provided by all progressive dealers for recleaning and grading seeds of grains, clovers, grasses, and other field and forage crops, but seed of cotton, the all-important money crop of the South, has not received in this respect the attention by commercial agencies that it deserves. This indifference may be partly because of the fact that the necessity for and value of recleaning and grading cotton seed have not been realized

fully; consequently progress in developing machines for the purpose has been slow. Also cotton seed as it ordinarily comes from the gin still contains sufficient lint to prevent the seeds from separating readily. This makes recleaning and grading difficult and probably accounts for a number of unsuccessful attempts to operate various machines now on the market. If properly delinted, however, as described on page 10, the surplus lint is removed, leaving the seed in such a condition that recleaning and grading is greatly facilitated.

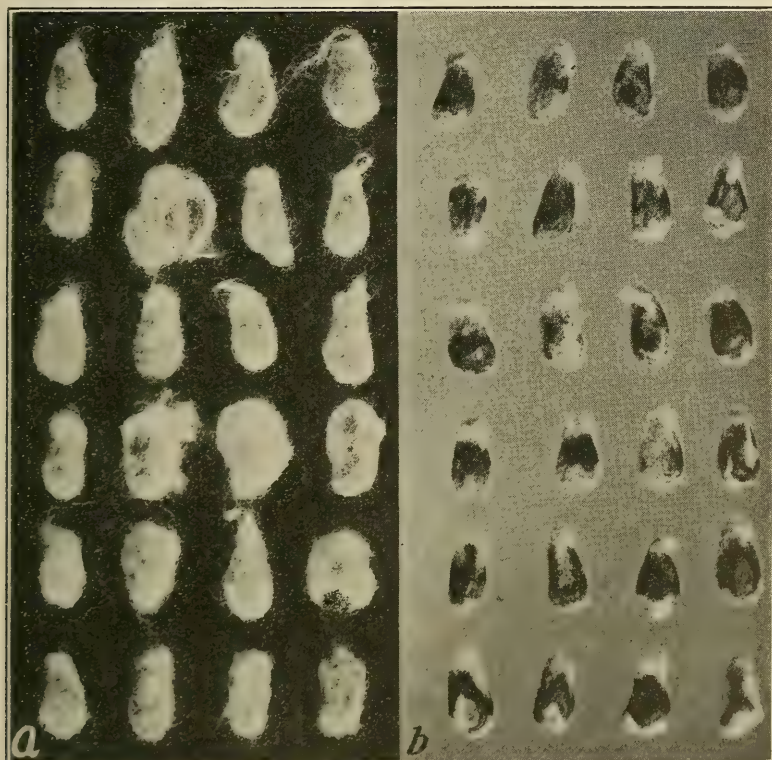


FIG. 6.—Cotton seed: *a*, Gin-run; *b*, closely delinted, showing black hull of seeds. Natural size.

The low average yield per acre is the greatest factor affecting the profitableness of the cotton-growing industry. Any practice resulting in an increased yield with only slight additional cost tends to lower the net cost of production per pound. In experiments conducted by the Bureau of Plant Industry,⁷ graded seed produced from 88½ pounds, or 8.25 per cent, to 103 pounds, or 10.9 per cent, more seed cotton per acre than ungraded seed. In preparing the seeds used in these experiments for grading it was necessary to roll

⁷ Webber, Herbert J., and Boykin, E. B.: The Advantage of Planting Heavy Cotton-seed, U. S. Department of Agriculture, Farmers' Bulletin 285. 1907.

them in some finely pulverized material sprinkled with water to paste down the surplus lint or fuzz so that they would separate readily. The addition of water and any foreign material, however, introduces a possibility of error in the grading because in some cases it changes the relative weight of the individual seeds. The mechanical process of removing the surplus lint or fuzz with delinting machines, as already described, conditions the seed for any recleaning and grading operation without permitting this element of error, and without making it necessary to dry the seed.

MACHINES USED.

There are several machines in limited use for recleaning and grading cotton seed. One type is a modified air-blast cleaner or fanning mill equipped with specially designed screens. A small-sized machine of this type, operated by either hand or power and having a capacity of 3 to 5 tons per 10-hour day, may be bought at from \$50 to \$60. A machine of larger capacity may be had if desired. Some of the earlier machines consisted principally of a revolving screen through which the seed passed and which was supposed to remove all dirt and other extraneous matter and small inferior seeds. Another more expensive machine, combining both the revolving-screen and air-blast principles, is in use by a few dealers. A large capacity cleaner, already described on page 10, is used in oil mills to remove stones, metallic substances, dirt, and loose lint from cotton seed before it enters the delinters, but this machine does not grade or separate the seeds in any way. All light and inferior seeds are not necessarily the smallest and an air-blast separation is essential if the seeds are to be graded according to their specific gravity.

DOCKAGE IN RECLEANING AND GRADING.

The percentage of good seed lost or culled out in recleaning and grading is very small. The percentage of total dockage (dirt, trash, and light and inferior seeds) removed will vary with the cleanness and uniformity of the seed. Most of the dirt and trash, however, are removed by the gins and delinters and the dockage in recleaning and grading delinted seed consists principally of small and light-weight seed. If the cotton seed has been carefully selected and properly ginned and delinted, the dockage in recleaning should not exceed 5 per cent. The dockage, however, is not a total loss, because the seed thus culled out may be sold for other purposes at slightly less than the original cost.

Several instances are reported where dealers have discontinued recleaning and grading after a short time because of the seemingly excessive dockage and heavy loss of apparently good seed. However, the removal of the chief hindrance to this work by delinting and the continued improvement in machines designed to perform it,

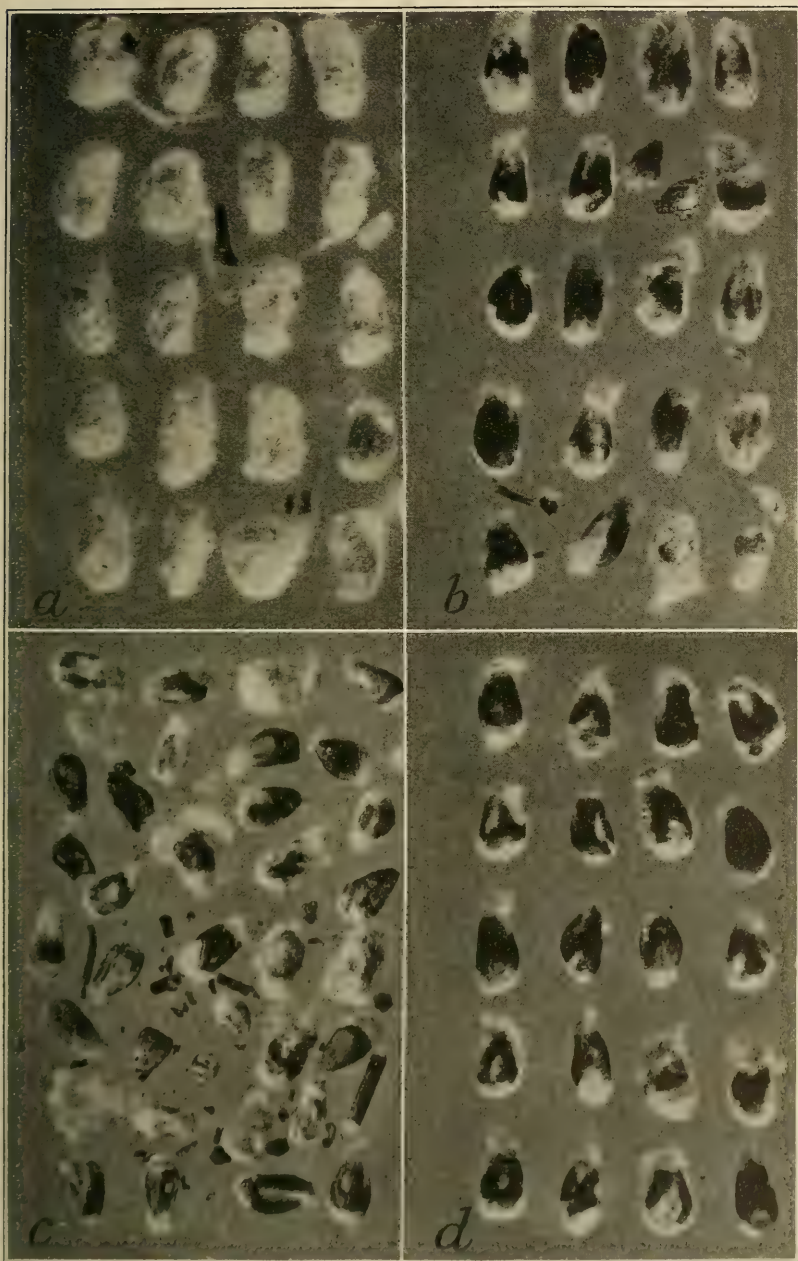


FIG. 7.—Cotton seed and classes of dockage removed in recleaning and grading. (a) Glurun seed; (b) delinted seed, not recleaned; (c) delinted seed, as in (b), but recleaned and graded, all trash, dirt, and light-weight, immature, or otherwise inferior seeds, as shown in (c), being removed by recleaning and grading machine, leaving every seed a potential plant. These samples were taken from a ginning, delinting, and recleaning and grading plant in regular operation. In recleaning and grading delinted seed (b), resulting in the quality of seed shown in (d), the total dockage by weight was about 4 per cent. (Natural size.)

should be a strong incentive for dealers to reclean and grade all planting cotton seed sold by them. The results of the operation should be seeds that are perfectly clean, more uniform in weight, and higher in germination, and that contain a relatively larger quantity of the stored nutriment necessary for the development of vigorous, rapid-growing, disease-resisting, and high-producing plants. Dirty, trashy, immature, or otherwise inferior seed have no place in the economical production of cotton, and the dealer will not offer for sale and the farmer will not buy such seed if they have the best interests of the cotton growing industry at heart. Figure 7 contrasts the appearance of gin-run, delinted, and recleaned and graded cotton seed and shows the classes of dockage removed by recleaning.

SACKING.

It is economy to sack cotton seed as it comes from the recleaning and grading machine. Storing it in bulk and sacking later necessitates rehandling, and two men will be required to do the work, whereas, if the recleaner and grader is equipped with a simple elevator and bagging attachment, one man can sack the seed as fast as it comes from the machine. An automatic weigher and bagger may be used profitably where large quantities of cotton seed, either alone or in connection with other kinds of seed, are handled.

New bags, either cotton or burlap, should be used. If cotton bags are preferred, it is not necessary that they be of the heavy grade used for grass, clover, and other small seeds. However, they should be strong enough to withstand rough handling in shipment. Bags of 8-ounce burlap are satisfactory and are much used, although sometimes bags of 10-ounce burlap or heavier are preferred. The bags should have a capacity of 100 pounds, net, when sewed or tied, and be filled to even weight. The strong point in favor of a bag of this size is that cotton seed always should be sold by the 100 pounds instead of by the bushel. This point is discussed more fully on page 22. In closing the bags, sewing either by hand or machine is preferable to tying.

STORAGE.

Cotton seed may be stored either in bulk or in sacks. In either case the main precaution is to prevent the seed from heating. Investigations show that the germination of cotton seed is injured oftener by heating in storage than is generally believed. The direct cause of such heating is excessive moisture. The extent of the damage from heating is directly in proportion to the percentage of moisture contained and indirectly to the rapidity of drying. Seed cotton picked early in the season while "green" or at any time when moist and stored in a close bin or building is subject to heating. If cotton is ginned while "green" and the seed stored in large piles such seed becomes heated quickly, and constant stirring or aerating is necessary if it is to be preserved for planting.

WAREHOUSE SHOULD BE VENTILATED.

The seed should be dry when stored and the warehouse well ventilated. A warehouse admirably serving the purpose is one having a floor clearance at least 12 inches above the ground, with double walls, and having ample ventilation under the floor and between the top of walls and roof. Concrete floors are not desirable, and, if the building is of brick or concrete construction, the seed, whether in bulk or sacked, should not be piled high against the walls, as considerable damage to the seed is likely to result. If, however, it is necessary to use a building having a concrete floor, the danger of heating may be lessened greatly if not entirely prevented, by sacking the seed and stacking the sacks, in the manner outlined on page 18, on a slatted false floor built by laying 2 by 4 inch stringers edge-wise on the concrete floor and nailing 1 by 4 inch strips across them leaving a 2-inch space between each strip. Similar results may be had by simply laying three 4 by 4 inch stringers on the floor about 8 inches apart and stacking the sacks on these in the same manner. Such a plan also may be used advantageously in buildings or on floors constructed of any other material.

A patented ventilating system, consisting of tubes 6 inches in diameter, made of perforated sheet metal or of heavy one-fourth inch mesh wire, which are placed upright over holes cut in the floor about 6 feet apart each way and which extend above the height of the walls of the building, has come into limited use in cotton-seed warehouses during recent years. When bulk seed is piled high in a building so equipped these tubes or "flues" provide a constant circulation of air.

If more than one variety or strain of a variety is stored in bulk in the same warehouse, separate bins should be provided and each bin marked with the lot number (see page 20) given to the particular strain or variety of seed stored therein. This arrangement will reduce the liability of varieties becoming mixed and identify the different lots. Some such means of identification is necessary because it is difficult, and in most cases impossible, to distinguish between the varieties by the appearance of the seed.

STORING IN SACKS.

Storing in sacks offers several advantages. Where the many phases of preparation are performed successively or as one continuous operation and the seed sacked at the recleaner and grader, there will be no occasion for storing in bulk. When sacked, the seed may be moved or transferred at will and shipments made with the least possible delay. Also when the bags are arranged in the warehouse in the manner described in the following paragraph, injury to the germination by heating is not so likely to result as when stored in bulk. The bags should be stenciled immediately after sacking with the lot number assigned to this particular lot of seed.

The best position for the stenciled number is across the top of the bag. In this position it will be visible when the bags are standing on end or when stacked or piled. All bags bearing the same lot number should be kept together and placed or stacked in the same section of the warehouse.

STACKING.

In stacking, it will be found advisable to alternate the position of the bags in each layer by placing a double row end to end in the first layer, and in the second or succeeding layer placing them parallel to each other and crosswise or at right angles to those in the first or preceding layer. This provides a stack or pile the width of the length of a bag and any desired height and length that the dimensions of the warehouse will permit. A space of at least 6 inches should be left between each stack or pile and between the bags and the walls. Such arrangement permits a free circulation of air and reduces greatly the possibility of heating.

GERMINATION.

All other factors being equal, the value of a given quantity of seed is in direct proportion to the percentage that will grow. Regardless of this fact, a widespread belief exists that the making of germination tests of planting cotton seed is of minor or secondary importance. This belief is based largely on two factors: (1) That seed from mature cotton harvested under favorable conditions and stored properly will germinate satisfactorily, and (2) that the heavy rate of seeding employed by most farmers will give a good stand of plants although a large percentage of the seed may not grow. These factors are true to a limited extent. However, two lots of seed may be handled and stored in exactly the same manner and yet there may be a wide difference in the percentage of germination. Also the farmer who buys planting cotton seed is entitled to know, so far as practicable, what percentage may be expected to grow in order that he may effect a corresponding saving in the cost of seeding by adjusting accordingly the quantity to be sown per acre.

The results of germination tests made by the Seed Laboratory, Bureau of Plant Industry, of samples submitted to the Bureau of Markets and Crop Estimates show that there is a wide variation in the viability of cotton seed sold for planting purposes. This variation occurs not only between the samples submitted by different dealers but also between the percentage of germinable seed in each of two or more samples submitted by the same dealer. For example, of the 1919 crop, one of five samples of as many varieties submitted by a dealer tested only 56 per cent, while the other four ranged from 80 to 93 per cent; and of the 1920 crop, one of four samples submitted by another dealer tested only 59 per cent, the other three 88, 88, and 94.5 per cent.

With further reference to the 1919 crop, the percentage of germination of the 70 samples tested ranged from 45 to 96 per cent, aver-

aging 82.5 per cent. Twenty-one of the samples tested 90 per cent or over, averaging 92 per cent; 28 tested 80 to 89 per cent, inclusive, averaging 85.7 per cent; these 49 samples tested 80 per cent or above, averaging 88.4 per cent, while the remaining 21 samples (30 per cent of the total) germinated less than 80 per cent, with the low average of 68.8 per cent. The 1920 crop samples tested averaged 85.3 per cent, or 2.8 per cent higher than those of the 1919 crop. This was to be expected because of the more favorable weather generally for harvesting the 1920 crop. However, of the 89 samples submitted, 17, or nearly one-fifth of the total, germinated less than 80 per cent, with the same low average of 68.8 per cent. If germination be used as the basis of values, the 1919 crop lots testing 80 per cent and over, averaging 88.4 per cent, are worth 28.5 per cent more, and the 1920 crop lots testing 80 and over, averaging 89.1 per cent, are worth 29.5 per cent more than those testing less than 80 per cent and averaging only 68.8 per cent.

CAUSES OF LOW GERMINATION.

Low germination may be caused by unfavorable weather conditions, delay in harvesting, and heating in storage. A severe drought during August and September usually results in immature or undeveloped seed of low viability. Wet weather, extending over a period of a week or more, causes more or less damage to the germination of the seed by the continued presence of excessive moisture in the bolls. Tests are on record⁸ of seed from cotton harvested after a long rainy season which averaged only 55 per cent germination and which ran as low as 29 per cent. Also tests⁹ of seed from cotton harvested in the early fall months showed an average of 90 per cent germination, while that from mature cotton harvested in January averaged only 43 per cent, and from frosted cotton harvested during the same month only 14 per cent germination.

MAKING TESTS.

One or more representative samples of each lot of seed should be taken at the time of sacking, and marked with the lot number, for use in making germination tests. The sample should contain at least 1 ounce of seeds, about 300, in order that duplicate tests, using 100 seeds in each, may be made and a part of the sample retained for check. If there is any probability that a lot of seed has become damaged, from any cause, prior to harvesting and ginning, such seed should be tested as soon as ginned or delinted, and held in bulk pending the results of the germination test before being recleaned and sacked. With the possible exception of cases where there may be a shortage of high germinable seed of a particular variety, there is no

⁸Arkansas Agricultural Experiment Station, Circular 22: Testing Cotton Seed for Germination.

⁹Arkansas Agricultural Experiment Station, Circular 37: Cotton Seed for Planting Purposes.

reason for retaining damaged seed for planting purposes. If such seed is sold for planting purposes a second test should be made at the time it is sacked and sales should be made on the basis of this latter test.

The equipment necessary in making reliable germination tests is not expensive. Commercial germinators are on the market at around \$50. Tests also may be made in sand or soil or by the use of blotting paper or cotton flannel placed between ordinary dinner plates and kept warm and moist. Samples also may be sent to the Seed Laboratory, Bureau of Plant Industry, Department of Agriculture, Washington, D. C., or to the Branch Seed Laboratory, College Station, Tex., for test without cost.

The method of making the test will depend upon the nature of one's relation to the planting cotton seed business and the quantity of seed sold annually. The main point is that a reliable test should be made. The method of testing by cutting the seed with a knife and examining and tasting the kernel is inaccurate, if not fallacious, can not be relied upon, and should not be used or advocated.

It is not proposed to fix a minimum or a standard percentage of germination at this writing, but rather to show that germination directly affects the commercial as well as agricultural value of planting cotton seed. The comparative commercial value of different grades of seed is governed largely by their agricultural value. A dead seed has no value for planting purposes. For this reason it is essential that accurate records of germination tests be kept so that the information may be passed on or made available to the farmer or other purchaser. These records should include the lot number of the seed from which the sample was taken, the date on which the test was made, and the percentage of germination as shown by the test. The duration of the test and any general remarks having a bearing on the viability of the seed or the vigor and healthfulness of the prospective young plants may be included.

THE SHIPPING TAG.

In addition to carrying shipping directions the shipping tag or label should also contain the following basic information which will aid the buyer in determining the true value of cotton seed: Lot number, variety, where grown, year grown, percentage of germination, and date of test. Many States in the cotton belt have enacted seed laws which require that additional information, such as the percentage of each of pure seed, weed seed, and inert matter, and the names of noxious weed seed present, be shown on the label attached to shipments of seeds, including cotton seed.

THE LOT NUMBER.

The lot number is the key to the identity of any particular lot of seed. If dissatisfaction arises over a shipment, the lot number on the

shipping tag or on the bag, with the aid of properly kept records, will aid in tracing the lot of seed from which the shipment in question was taken, through each step of its preparation for the market back to its source of production. The original cause of the dissatisfaction would thus be located and responsibility properly placed. Information regarding the name and address of grower, location of farm, variety grown, and origin of stock seed as well as data on germination referred to on page 20 also should be recorded in connection with each lot number.

SELLING.

The indiscriminate buying and selling of field-crop seeds with little or no regard for the purity of variety or genuineness of strain is one of the greatest evils in the seed trade. A sale of cotton seed for planting purposes represents something more than ordinary merchandising. It has a direct bearing on the crop that may be produced. The value of the seed is potential, not apparent, and the farmer in making purchases has to rely almost wholly on the integrity of the seller and the accuracy and completeness of his statements.

EXTRAVAGANT CLAIMS UNDESIRABLE.

A glance at the advertisements, catalogues, circulars, and other printed matter issued by various cotton-seed dealers will disclose many extravagant claims and inconsistent statements. In some cases these claims are gross misrepresentations, and are never sustained except under the most favorable conditions or by the sacrifice of other equally important characteristics. The outstanding inconsistency in such statements is the fact that in many cases they attempt to describe the good points of a variety and to show its agricultural possibilities when an examination of the seed for sale would show it to be mixed, poorly ginned, and often low in germination. Farmers generally are familiar with the description and characteristics of the most widely grown varieties of cotton, and it is of far greater importance for dealers to give assurance that the seed offered for sale is pure as to variety, in good physical condition, and of high germination. The policy of simply listing cotton seed by its true variety name and stating in detail the conditions under which a particular lot was produced, special methods employed in preparing it for planting purposes and for market, and the percentage that may be expected to grow would indicate more clearly its actual commercial and agricultural value. The farmer, the ultimate purchaser and consumer, being already familiar with the possible results to be obtained from planting a particular variety of cotton, should be more interested in knowing whether the lot of seed purchased is pure, unmixed, well ginned or delinted, recleaned and graded, and of high viability. Cotton seed with each individual seed a potential plant, not descriptive variety information, is the commodity to be sold or to be purchased.

TRUE NAMES FOR VARIETIES.

The number of variety names used by growers and dealers in selling planting cotton seed during comparatively recent years runs into hundreds. Over 50 variety names are employed by dealers at present. A number of these names, however, are merely trade names and do not represent a distinct variety. The diversity of designations for the same variety is still further increased by applying various descriptive terms. For example, the King variety is found to be listed in 12 forms as follows:

King.	King's Extra Early.
King's Early.	King's Early Improved.
King's Improved.	Re-Improved Early King.
Early King.	Faultless Bred King.
Improved King.	King's Improved Extra Early.
Re-Improved King.	King's Extra Early Big Boll.

The names of many other varieties are altered in much the same manner. A farmer in the market for cotton seed would have difficulty in determining from such an array of titles when he was getting the best value or the highest grade of seed of the desired variety. To apply complex adjectives to the true variety name not only confuses but in some cases may mislead the buyer. Sometimes dealers use only such descriptive phrases as "Big Boll Early," "Early Prolific," etc., without tying them up to the variety name or indicating in any way what variety is represented. Such practices should be discontinued.

RENAMING VARIETIES.

The practice of renaming varieties of cotton has been greatly abused. To grow or purchase cotton seed of a well known or common variety or of mixed varieties, and sell it under an unknown name with glowing descriptions, implying that results hitherto not attained may be expected, is a policy to be condemned. Practices of this kind serve only to bring the planting cotton seed business into disrepute and tend to discredit the honest efforts of conscientious seed breeders and dealers. The latter should be encouraged because the development and distribution of new varieties and improved strains maintain or raise the standard of cotton production to a great extent. When seed of a new variety of cotton is offered to the public, its origin, method of developing, tests made and results obtained, its soil, climatic, and regional adaptations, and the reputation of the originator are factors which should be considered in passing judgment on its true value. The seller should see that these facts are stated fully and accurately and made available to the buyer.

SALES ON BASIS OF WEIGHT VS. MEASURE.

The sale of planting cotton seed on the basis of weight rather than measure is strongly urged on all persons or concerns handling this commodity. It seems inconsistent, to say the least, for planting cot-

ton seed to be sold on the bushel basis when the market for cotton seed for manufacturing purposes, which quantity is ten times as large, is firmly established on the 100-pound or ton basis. The outstanding argument in favor of sales for planting purposes being made on the 100-pound or ton basis, however, is the wide variation in the established legal weights per bushel in the cotton-producing States. In North Carolina, South Carolina, and Georgia the legal weight per bushel of upland cotton seed is 30 pounds; in Alabama, Mississippi, Oklahoma, and Texas, 32 pounds; in Arkansas $33\frac{1}{2}$ pounds; and in Tennessee, only 28 pounds. At the present time most dealers in the various States do not adhere strictly to the legal bushel weights designated, but avoid any probable recourse in transactions by quoting prices per bushel of a specific number of pounds, which may or may not be the prescribed legal weight in their respective States. Although the legal weight of a bushel varies from 2 to 5 pounds in different States, the pound remains constant, and the difficulties and misunderstandings attending the lack of uniformity in bushel weights can be avoided by adhering strictly to the practice of quoting prices per 100 pounds.

CERTIFIED COTTON SEED.

In view of the fact that authentic information or assurance regarding the purity as to variety and trueness to type of cotton seed has an important bearing on its value for planting purposes, it seems that some system of certification would be desirable. Certified seed of potatoes, rye, alfalfa, and a few other crops are available in limited commercial quantities, but little work of this kind has been done with reference to cotton. The registration, inspection, and certification of cotton fields from which planting seed is to be selected, by some disinterested agency, would go a long way toward providing a commercial supply of cotton seed pure as to variety and true to type. It remains for State and Federal agricultural agencies to work out a method that will be practical in its application and that will effect the desired results. Certified cotton seed, however, with all that the term implies, would not represent the ultimate in planting cotton-seed values unless the seed also be subjected to approved methods of preparation and marketing.

SUMMARY.

The ideal planting cotton seed may be described as seed selected from cotton that is true to type and pure of variety, well matured, free from disease and insects or insect injury, delinted, re-cleaned and graded, and testing a minimum of 88 per cent germination.

It is necessary that the stock seed used in producing cotton from which commercial planting seed is selected should compare favorably with the ideal.

The more thorough and uniform removal of the surplus lint and culling out of all extraneous matter and small or light inferior seed

would result in a possible reduction of 100,000 tons of cotton seed in the annual seeding requirements and a saving of 30,000,000 pounds of linters for industrial purposes which are now wasted.

The cost of delinting should not exceed \$5 per ton, while the agricultural value of the process in promoting quicker and more uniform germination with less seed per acre is much greater.

Delinting also facilitates recleaning and grading by removing the surplus lint or fuzz which prevents the seeds from separating readily when subjected to an air blast or when passing over a screen.

The results of recleaning and grading are clean seed, uniform in weight, high in viability, and containing a relatively larger quantity of stored nutriment necessary to the production of well-developed, vigorous, rapid-growing, disease-resisting, and high-producing plants.

It is economy to sack cotton seed as it comes from the recleaning and grading machine. The bags should have a capacity of 100 pounds net when sewed or tied and be filled to even weight.

Cotton seed stored in sacks and stacked so as to permit ventilation is less subject to heating, which seriously impairs germination.

All other factors being equal, the value of a given quantity of planting cotton seed is in direct proportion to the percentage that will grow, and a reliable test of the germination of each lot should be made and sales made on this basis.

The shipping tag should convey the following information to the buyer, the farmer: Lot number, variety, where grown, year grown, percentage of germination, and date of test.

The lot number is the key to the identity of any particular lot of cotton seed, in connection with which records should be kept regarding the name and address of grower, location of farm, variety, and origin of stock seed, as well as data on germination.

Listing cotton seed by its true variety name and stating more in detail the conditions under which it was produced, special preparation given it for planting purposes and for market, and the percentage of germination indicates more clearly than present methods its actual commercial and agricultural value.

There is a difference of 2 to 5 pounds in the legal bushel weights of upland cotton seed in the various cotton States, and the sale of planting cotton seed on the basis of weight instead of measure is strongly advocated.

The registration, inspection, and certification of cotton fields from which planting seed is to be selected, by some disinterested agency, would go a long way toward providing a commercial supply of cotton seed pure as to variety and true to type, but this would not represent the ultimate in planting cotton seed values unless it is delinted, recleaned and graded, and of the highest practicable percentage of germination.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1057

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

April 24, 1922

THE CHAULMOOGRA TREE AND SOME RELATED SPECIES: A SURVEY CONDUCTED IN SIAM, BURMA, ASSAM, AND BENGAL.

By JOSEPH F. ROCK, *Agricultural Explorer, Office of Foreign Seed and Plant Introduction.*

With an Introductory Chapter by David Fairchild, Agricultural Explorer in Charge of the Office of Foreign Seed and Plant Introduction, and a Chapter on the Chemistry of Chaulmoogra, Hydnocarpus, and Gynocardia Oils by Frederick B. Power, Chemist in Charge of the Phytochemical Laboratory of the Bureau of Chemistry.

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INTRODUCTION.

By DAVID FAIRCHILD, *Agricultural Explorer in Charge of the Office of Foreign Seed and Plant Introduction.*

Although chaulmoogra oil has been in use for hundreds of years by the natives of India in the treatment of leprosy, it is only recently that a general public interest has been aroused in it. This is due to the successful treatment of the disease with certain constituents of the oil by Drs. Hollmann, Dean, and McDonald, in the Hawaiian Islands. (11, 15, 16).¹

Whereas the East Indians used the crude oil expressed from the seeds as a local application and also internally, the above-mentioned

¹ The serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

investigators employed, by intramuscular injection, the ethyl esters derived from its peculiar fatty acids.

In 1918 the Kalihi receiving station² invited Dr. A. L. Dean, professor of chemistry and president of the University of Hawaii, to cooperate in determining which of the constituents of chaulmoogra oil possessed specific value in the treatment of leprosy. Basing his work upon the exhaustive researches of Dr. Frederick B. Power and his collaborators in London (1, 17, 18, 19, 20, 21), who first isolated and described the optically active chaulmoogric and hydnocarpic acids and prepared their esters, Dr. Dean (6), in collaboration with Dr. Richard Wrenshall, undertook the fractionation of chaulmoogra oil in order to ascertain the best method of preparing the acids and their respective ethyl esters in quantities sufficient for clinical use. By means of a high vacuum the acids were obtained in a satisfactory degree of purity.

The standard treatment consisted at first of weekly intramuscular injections of the mixed ethyl esters with 2 per cent of iodine in chemical combination. These injections were supplemented by the oral administration of the fatty acids with 2.5 per cent of iodine, this preparation being given in capsules three times a day.

The method of treatment was later changed by omitting the iodine and also the oral administration of the acids, as it was found that this procedure was not necessary and that the injection of the ethyl esters was vastly more important. It was furthermore observed that the mildest forms of the disease showed the slowest improvement. One of the difficulties encountered in treating patients is said by Drs. McDonald and Dean to be that something like 10 per cent of them are unable to take the injections continuously, as they tend to break out with swellings, which may be a form of toxemia or an anaphylactic reaction.

While it is a fact that it will require a period of several years to demonstrate that persons treated with the ethyl esters of the acids obtained from chaulmoogra oil are absolutely cured of leprosy, the indications of their curative action after nearly two years of use have been so promising as to make a thorough study of the trees which furnish this oil and some closely related products extremely advisable. That the above-mentioned preparations have been of immense help in the treatment of the disease is beyond question. McDonald and Dean (16, p. 1473) have, indeed, considered it to be established "that the fatty acids of the chaulmoogric series are specific in leprosy."

²This institution is located in the suburbs of Honolulu, where for many years those suspected of having leprosy were received for examination and whence those affected were sent to the leper settlement of Molokai.

The evidence afforded by the many cases treated at the receiving station and released as cured, of which not one has been returned because of a recurrence of the disease, is, to say the least, most significant. This is especially true when taken in connection with the disintegration of the bacillus, as observed under the microscope, in the tissues of treated as compared with untreated patients.³

The purpose of the botanical explorations undertaken by Prof. Rock, of which this is a preliminary report, was to promote the cultivation of the chaulmoogra tree and thus insure such a supply of the genuine oil as would meet the demand created by the above-noted therapeutic investigations.

HISTORY OF CHAULMOOGRA OIL.

By JOSEPH F. ROCK, *Agricultural Explorer, Office of Foreign Seed and Plant Introduction.*

Chaulmoogra seeds and chaulmoogra oil have been known for centuries to the natives of Burma and southeastern Asia in general as palliatives in leprosy and other skin diseases and were employed by them both externally and internally. The species most used has been *Taraktogenos kurzii* King (family Flacourtiaceæ, or Bixineæ as it is called in the Bentham and Hooker system), which the Burmese call kalaw, also kalawbin (the tree), while the fruits are known as kalawthee. This same species is known as lemtam in Assam, chaulmoogra or chaulmugra in Hindi and Bengali, and to the Arakanese as toung-pung. The Mikir name is thibong-thar; the Kachin name, ser-buli-baphang; and the Miri name, seeri-asing.

Up to the present day, seeds of what is now known as *Taraktogenos kurzii* and of closely related species, such as *Hydnocarpus castanea*, both of which are called kalaw in Burma, are sold in the native bazaars throughout that country; in fact, seeds of the former are brought across the Burmese Mountains to Siam, where they are offered for sale in native drug shops as far north as Chiangmai. The seeds sold in these bazaars are usually old and rancid, with an exceedingly high acid content, and they are probably of inferior value from a medicinal standpoint.

Before relating the more recent history of the species, *Taraktogenos kurzii*, which yields the genuine chaulmoogra oil, there may be given a free rendition of certain excerpts from the "Mahawin," the

³ In a communication from Dr. McDonald (15) to the Journal of the American Medical Association, he refers to a previous publication on the derivatives of chaulmoogra oil, in which the apparent cure of 78 cases of leprosy was reported, and remarks further: "As supplementary to that report I wish to add that during the present month, after an examination by a committee of physicians representing the Territorial board of health, 64 additional patients have been released from Kailhi (Leprosy) Hospital on parole as no longer a menace to the public health, and 142 patients have been paroled since October 1, 1918, not one of whom thus far has suffered a relapse."

history of the Buddhas and their Rahandas, relating to the kalaw tree, which were kindly translated by Mr. A. Nicholas, deputy revenue collector of the Upper Chindwin district, Mawlaik.

This legend relates that in the days of yore, before the time of Buddha, there reigned a king in northern India by the name of Ok-sa-ga-rit. This king had five sons and five daughters. These five princes exiled themselves, and their sisters volunteered to do the same, owing to the naming as heir apparent of a younger (sixth) prince, a son by a second queen. The story relates that Piya, the eldest sister of these five princes, who was much honored and revered, became a leper. The brothers and sisters, for fear of wounding her feelings, took her into the jungle, as if going on a pleasure trip, and when they arrived at a certain place where there was a cave they left her there with all kinds of provisions. The cave, which had a very narrow entrance, was well protected.

At the same time Rama, once the king of Benares, was living in the jungles under the following circumstances: When king of Benares, he became afflicted with leprosy, and although his court physicians did their best they failed to relieve him from his sufferings or to improve his condition. He decided to abdicate the throne in favor of his son and, leaving the palace, went into the jungles and existed entirely on herbs and roots, but especially on the fruits and leaves of the kalaw tree. After a time he was completely cured and felt better and stronger than when he lived in the palace surrounded with luxury. He lived in the hollow of a large tree, which he converted into a home.

One day a tiger, when prowling near Piya's cave, was attracted by the odor of a human being. It made frantic efforts to gain entrance to the cave. Piya was so horrified that she gave a piercing scream. Rama heard the cry from his hollow tree and noted the direction whence it came. Next day he went in search of the person who gave the agonizing cry. He discovered the cave and shouted, "Who lives in the cave?" Piya, hearing a human voice, replied and after the usual greetings explained her circumstances. He asked her to come out, but she refused, being shy and modest. So Rama forced his way into the cave and carried her off to his hollow tree. He then made her eat the fruits, roots, and leaves of the kalaw tree which had wrought such a wonderful cure for him. She was soon cured, and Rama took Piya unto himself as his wife. Piya gave birth to twins sixteen times, bearing 32 sons. A hunter from Benares one day came to this part of the jungle and recognized Rama as the former king of Benares. Seeing so many young princes, the hunter asked who they were. Rama explained the circumstances, and the hunter on his return to Benares related the whole story.

to the king, who was none other than Rama's son. The king came with a great retinue to Rama and asked him to return to the palace, but Rama refused, saying "I will found a new city here. Get your men to clear away all the kalaw trees." The new city was called "Kalanagara," as it was built on the spot where kalaw trees once grew. It was also known as "Byetgyapata," as the tigers used to eat their prey in this place. Rama's son then returned to Benares.

So much for ancient native legends regarding the curative properties of the kalaw tree in leprosy.

For nearly a hundred years the seeds of the kalaw tree, now known as *Taraktogenos kurzii*, were thought to be those of a tree listed by Dr. William Roxburgh in 1815 in his *Hortus Bengalensis* (22) as *Chaulmoogra odorata*. This was accepted as the source of chaulmoogra oil. In 1819 R. Brown (23, p. 95) described the plant under the name of *Gynocardia odorata*, discarding Roxburgh's *Chaulmoogra odorata*, as no description was published, the name only being given. Warburg (24, p. 22, fig. 6, M N) figures the seeds of *Taraktogenos kurzii* King as those of *Gynocardia odorata* R. Br.

M. G. Desprez, a French pharmacist, was the first to discover that the seeds of what is now known as *Taraktogenos kurzii* were not those of *Gynocardia odorata*, and he decided that they belonged to another species of this genus, which he called *G. prainii* in honor of Col. David Prain, director of the botanical survey of India. This was, however, a mistake, as the seeds sold as chaulmoogra seeds in the bazaars of India were not those of a *Gynocardia*. Their identity was left for Col. Prain himself to discover.

In 1898 A. Bories, in the introduction to a paper entitled "Contribution à l'Étude thérapeutique de l'Huile de Chaulmoogra gynocardée" (3, p. 12) makes the following statement:

The skepticism professed by a large number of physicians is to a certain extent justified and must be respected when one considers the numberless advertisements of panaceas with which a shameless quackery fills the fourth page of our newspapers; but it seems to us that this restraint should be broken down by well-attested records of cures which have been presented by men whose studies and experience entitle them to our confidence.

For several years, therefore, our efforts have been toward the end of popularizing and recommending in France a medicine of remarkable efficacy, the value of which has been proved empirically by the natives of a far-eastern country during a period of more than two centuries. . . . We have never pretended to offer the medical world a new remedy; our aim has been simply to call attention to its efficacy and to prove its value by presenting an abundance of evidence. We are presenting herewith the observations which certain physicians, at our request, have made regarding the use of this medicine in a large number of cases.

The remedy to which we wish to call attention is gynocardic chaulmoogra oil, extracted from the seeds of *Gynocardia odorata*.

Bories was the first to introduce the drug into France. On page 4 of the above-mentioned paper he says, regarding the seeds: "Their albumen is plentiful, oily, and holds a pair of flat foliaceous heart-shaped cotyledons with a bulky radicle." This shows at once that Bories undoubtedly had *Taraktogenos kurzii* seeds, as those of *Gynocardia odorata* have no foliaceous cordate cotyledons and have a lateral instead of a basal radicle.

In the year following (1899) Desprez made the discovery that the seeds used were not those of *Gynocardia odorata*.

To George Watt, the reporter on economic products of India, much credit is due for solving the mystery regarding the true source of chaulmoogra oil. Watt had plants collected, through the conservator of forests of the Chittagong division, of what purported to be the source of chaulmoogra oil. They were collected in the Kassalong forests in the Chittagong Hill tracts. Watt sent the specimens to Col. Prain, who, in a letter to Watt, dated June 28, 1900, wrote as follows:

Your 14421 from Chittagong is a great find. These are the real chaulmoogra seeds of the Calcutta bazaar and of the Paris and London drug dealers. It is certainly not a *Gynocardia*. I believe it is a *Hydnocarpus* and so now do my friends in Paris. . . .

Col. Prain finally identified it with a plant collected by S. Kurz in Pegu, Burma, which Kurz had erroneously regarded as *Hydnocarpus heterophylla* Bl. (a species occurring in Java), but which Sir George King, who worked up the species of *Hydnocarpus* and *Taraktogenos*, had described in 1890 as a species of *Taraktogenos* and had named *T. kurzii* in honor of the collector. The source of the true chaulmoogra oil was thus established.

A number of species known as kalaw occur in Burma, however, especially in Lower Burma; and the seeds of these species, which resemble those of *Taraktogenos kurzii*, are also sold on the market and in the bazaars. One of these so-called kalaw trees the writer had an opportunity to identify as *Hydnocarpus castanea* Hook. f. and Thoms.; it occurred in the Martaban Hills of Lower Burma. It is quite probable, then, that not only *Taraktogenos kurzii* but, to a less extent, closely allied plants, such as *Hydnocarpus castanea* and other species of *Hydnocarpus* and *Taraktogenos* as yet undescribed, are sources of the chaulmoogra oil of commerce. No absolute statement of the source of commercial chaulmoogra oil can therefore be made so long as the seeds are gathered from wild-growing trees in different parts of Burma, Lower Bengal, and Assam. Only when *Taraktogenos kurzii* is grown as a plantation crop for the production of the oil can a definite statement be made with regard to the source and purity of the latter.

CHEMISTRY OF CHAULMOOGRA, HYDNOCARPUS, AND GYNOCARDIA OILS.

By FREDERICK B. POWER, *Chemist in Charge of the Phytochemical Laboratory of the Bureau of Chemistry.*

The attention which has recently been drawn to the successful treatment of leprosy by the use of certain acids contained in chaulmoogra oil, or esters prepared therefrom, renders it desirable that some account should be given of the original researches which led to their discovery and thus made them available as therapeutic agents. The investigations to be considered here, unless otherwise specified, were conducted several years ago in the Wellcome Chemical Research Laboratories, London, and comprised not only an examination of the true chaulmoogra oil but also some related products. Prior to these investigations nothing of a definite nature was known concerning the chemical constituents of these oils, and the statements in the literature concerning them were very superficial and inaccurate.

I.—CHAULMOOGRA OIL.

An authoritative definition of chaulmoogra oil is that given by the British Pharmacopœia, 1914 (9, p. 262), which states it to be "the fatty oil expressed from the seeds of *Taraktogenos kurzii* King." The acceptance of this definition is important, especially on account of a prevailing tendency to designate the oils from some closely related botanical sources as chaulmoogra oil. It has been shown, however, that the oils from certain species of *Hydnocarpus* are very similar to the true chaulmoogra oil in their physical characters and chemical composition, and they are known to be used for the same purposes in the countries of their production. There would therefore seem to be no reason for excluding such oils from medicinal use when their botanical source is designated.

It is not necessary in this place to enter into all the details of the respective investigations, especially as a complete account of them may be found in easily accessible chemical literature (1, 18, 19, 21). It may be stated, however, that in all cases the oils examined by the present writer and his collaborators were expressed under the most careful supervision from seeds which had been freshly collected and botanically identified. There was thus complete assurance of their authenticity and purity.

Chaulmoogra oil is either a brownish yellow liquid or a soft solid which melts at about 22° to 30° C. It possesses a characteristic odor and somewhat acrid taste. The oil consists to a large extent of the glyceryl esters of optically active acids of a type which had not previously been found to occur in any fatty oil. These acids are represented by the general formula $C_nH_{2n-4}O_2$ and have a cyclic structure.

The acid present in the largest proportion possesses the formula $C_{18}H_{32}O_2$, and has been designated chaulmoogric acid, with reference to the vernacular name of the oil. It is accompanied by a lower homologue, $C_{16}H_{28}O_2$, which has been termed "hydnocarpic acid," on account of having first been isolated from a *Hydnocarpus* oil. Both of these acids are beautifully crystalline substances, from which a number of derivatives have been prepared, and their constitution has also been definitely established. They constitute what is now known as the chaulmoogric acid series.

Chaulmoogric acid, $C_{18}H_{32}O_2$, melts at 68.5° C. and is dextrorotatory, having $[\alpha]_D + 62.1^{\circ}$. Although isomeric with linolic acid, it is capable of combining directly with only two atomic proportions of bromin or iodin. It must, therefore, possess only one ethylenic linking and contain in its structure a closed carbon ring, which has been shown to be the case. The methyl ester (methyl chaulmoograte) distills at 227° C. under a pressure of 20 mm. as a colorless oil, which on cooling forms a solid mass of needles, melting at 22° C. The ethyl ester (ethyl chaulmoograte) is a colorless oil, which boils at 230° C. under a pressure of 20 mm.

Hydnocarpic acid, $C_{16}H_{28}O_2$, melts at 60° C. and like chaulmoogric acid is optically active, having $[\alpha]_D + 68^{\circ}$. Its methyl ester is a colorless oil, which boils at 200° to 203° C. under a pressure of 19 mm. When cooled it solidifies to a mass of colorless crystals, which melt at 8° C. The ethyl ester is a colorless oil, which boils at 211° C. under 19 mm. pressure.

Besides the above-mentioned acids, chaulmoogra oil contains a small amount of palmitic acid, together with an acid or acids having a higher iodine value than either chaulmoogric or hydnocarpic acid. As was noted several years ago, this observation, in connection with other characters of the acids, indicated the presence in the oil of an acid or acids of the series $C_nH_{2n-4}O_2$, but with two ethylenic linkings. Inasmuch as linolic acid, $C_{18}H_{32}O_2$, possesses two ethylenic linkings and an iodine value of 181.2, it is probable that a considerable proportion of this acid is contained in both chaulmoogra and *hydnocarpus* oils. Linolenic acid, $C_{18}H_{30}O_2$, which contains three ethylenic linkings and has an iodine value of 273.7, may also be present.

An interesting occurrence of chaulmoogric acid has been recorded by Goulding and Akers (8, 10). They obtained it from the fatty oil of so-called "Gorli" seed from Sierra Leone and found it to be present to the extent of 84.5 per cent in the mixed acids, the remainder consisting of liquid acids having a higher iodine value and therefore more unsaturated. The botanical source of these seeds is *Oncoba echinata* Oliver, which belongs to the same family as the chaulmoogra tree.

II.—HYDNOCARPUS OIL.

The first hydnocarpus oils to be completely investigated were those expressed from the seeds of *Hydnocarpus wightiana* Blume and *H. anthelminthica* Pierre (18). They were found to resemble chaulmoogra oil very closely, both in their physical characters and in their chemical composition. Like the true chaulmoogra oil (from *Taraktogenos*), they consist to a large extent of the glyceryl esters of chaulmoogric and hydnocarpic acids, and it may therefore be inferred that they possess similar medicinal value. The fatty oils obtained from the seeds of these two plants have, indeed, long been used in western India and in China for the same medicinal purposes for which chaulmoogra oil is employed.

De Wolff and Koldewijn (25) determined the physical constants of the oil from *Hydnocarpus alpina* Wight and found them to agree rather closely with those of chaulmoogra oil. The oil from *Hydnocarpus venenata* Gaertn. was shown by Brill (4) to contain both chaulmoogric and hydnocarpic acids, and the same investigator has stated (5, p. 45) that more than 90 per cent of the free acids from the oil of *Hydnocarpus alcalae* C. DC. consist of a compound identical in properties with chaulmoogric acid.

III.—GYNOCARDIA OIL.

Gynocardia oil is obtained by expression from the seeds of *Gynocardia odorata* R. Br., which do not appear to be collected for commercial purposes. Prior to the year 1900 it was generally believed that the chaulmoogra oil of commerce was obtained from this botanical source, and the terms "chaulmoogra oil" and "gynocardia oil" were therefore considered to be synonymous. This confusion became extended to the fatty acids, in so far that an indefinite mixture of acids from chaulmoogra oil was designated many years ago as "gynocardic acid," and this misnomer is still frequently encountered in current literature. It has, however, been shown, as noted in this bulletin, that the true chaulmoogra oil is obtained from the seeds of *Taraktogenos kurzii* King, and this botanical observation was confirmed by a chemical examination of the oil from carefully identified *Taraktogenos* seeds. This perfectly authentic product was moreover found to agree in character with the chaulmoogra oil of commerce. On the other hand, it was subsequently shown that the oil expressed from freshly collected and carefully identified seeds of *Gynocardia odorata* differs completely from chaulmoogra oil, both in its physical characters and in its chemical composition (18, p. 896).

Gynocardia oil at ordinary temperatures is a pale-yellow liquid, having an odor resembling that of linseed oil. The specific gravity

of the freshly expressed oil was 0.925 at 25° C. It is completely devoid of optical activity, whereas chaulmoogra oil, as already noted, is strongly dextrorotatory, and it also differs from the latter oil by containing none of the members of the chaulmoogric acid series.

Gynocardia oil has been shown to consist of the glyceryl esters of the following well-known acids: (1) Linolic acid, or isomerides of the same series, constituting the largest proportion of the oil; (2) palmitic acid, in considerable amount; (3) linolenic and isolinolenic acids, the latter preponderating; and (4) oleic acid, in relatively small amount.

Gynocardia seeds contain, in addition to the fatty oil, a crystalline cyanogenetic glucoside, $C_{13}H_{19}O_9N$, which has been designated gynocardin, and an enzyme, termed gynocardase (21).

RECENT INFORMATION ON THE CHAULMOOGRA TREE AND SOME RELATED SPECIES.

By JOSEPH F. ROCK, *Agricultural Explorer, Office of Foreign Seed and Plant Introduction.*

HYDROCARPUS ANTHELMINTHICA.⁴

In 1919 the writer visited Bangkok en route to Singapore and Java. While at Bangkok inquiry was made regarding *Hydnocarpus anthelminthica*, but not much information was obtained. Dr. Mordern Carthew, resident physician and director of the Insane Asylum of Bangkok, had paid special attention to leprosy and for a number of years had treated the lepers in the Bangkok prison. He treated these lepers of his own accord with Dr. Leonard Roger's gynocardate of sodium "A"⁵ by intravenous injection and with tablets by mouth. Reports regarding his successes and failures with Roger's medicaments have been published. While at the insane asylum one day Dr. Carthew showed the writer a tree growing in the asylum compound. This tree, which he said was called maikrabao or lukrabao by the Siamese, proved to be none other than *Hydnocarpus anthelminthica* Pierre. About a dozen fruits were obtained at that time and the seeds forwarded to Honolulu, Hawaii, where they promptly germinated.

In 1920 the writer again visited Siam and made it a point to locate *Hydnocarpus anthelminthica* in its native haunts. It was exceedingly difficult to obtain any information about this species, even from the Government forest office. The tree is grown as an ornamental and is exceedingly handsome when well taken care of. It has been ex-

⁴ *Hydnocarpus anthelminthica* Pierre (7, p. 523). Mentioned without adequate description in Lanessan (14, p. 303). Specimens collected by the writer are deposited in the United States National Herbarium: Rock No. 1189, U. S. N. H. Nos. 1,090,027 and 1,090,028; Rock No. 497, U. S. N. H. No. 1,090,003.

⁵ A sodium compound of the higher fatty acids of chaulmoogra oil.

tensively planted in the temple grounds of "Wat Benchamo Pobit" in Bangkok. A street in Bangkok passing directly to the rear of the so-called golden mound, an artificial hill with a pagoda at the top, is also planted on both sides with this species. Here the trees are certainly not an ornament; they are in a very poor condition, are never watered, and grow directly in the hard roadbed. They were, however, loaded with fruits, and male flowers could also be found, but no female flowers (which evidently appear later, this being November). It seems that male flowers appear oftener, perhaps in the winter and again in April; and the fruits found on the trees, although not quite ripe when first seen in November, must have been from April flowers, or perhaps from November flowers of the year previous. No one seemed to know anything about the fruiting habits of this species save that all agreed that July was the real fruiting season. Fruits of the trees from the street in Bangkok were generously given me by the municipal government of Bangkok, and the seeds were forwarded to Honolulu, Singapore, and Washington. In the two former localities they germinated splendidly, but with a few exceptions failed to grow in Washington. There are several thousand trees of this species now growing in Hawaii.

While on an exploring trip in northern Siam in company with Mr. George P. W. Hunt, the American minister, the writer was informed by H. S. H. Princess Bovaradej, the wife of the Viceroy of Chiangmai, whose guest he was, that maikrabao, or *Hydnocarpus anthelminthica*, grew plentifully in eastern Siam, near Korat, the capital of that Province. Meanwhile, he inquired regarding this species of Dr. James W. McKean, superintendent of the leper settlement of Chiangmai, and it was found that several trees were in cultivation in Chiangmai proper. Later, Dr. McKean received from natives large quantities of seeds from a locality several miles down the Mehping River. It is presumed, however, that they were obtained from cultivated trees.

On the writer's return to Bangkok he made arrangements to visit Korat, in eastern Siam. Through the forest office there it was learned that maikrabao was not uncommon in the neighborhood, but that many of the trees had been felled and were constantly being cut down for firewood. On inquiry from an old Siamese ranger it was found that the species occurred near a place called "Lad-buakao." Thither the writer went by rail, and thence under the efficient guidance of Kun Anawat, forester, crossed into the forests through the rice fields and wild bamboo groves. On the banks of a klong, or estuary, *Hydnocarpus anthelminthica* was found growing much taller and handsomer than any cultivated specimen seen in Bangkok. (Pl. I.) Its roots probably receive a great deal of water,

as the tree grows along the banks of this klong, the waters from which must inundate the surrounding land in the rainy season. It grew in company with *Dipterocarpus alatus*, *Melia arborea*, *Salix* sp., and other trees of which specimens have been collected but are as yet unidentified. The leaves of wild-growing *Hydnocarpus anthelminthica* are not as narrow as those of cultivated specimens, but are lanceolate instead of linear-lanceolate (Pl. II). No mature fruits were found, but semiripe fruiting specimens were collected.

The natives of Siam use the seeds of this species for the expression of an oil which they apply in cutaneous affections. It was stated by natives that the fruits are poisonous and also that fish feeding on the seeds of maikrabao are unpalatable. The narcotic properties of the seed are imparted to the fish, which, when eaten, produce nausea and vomiting.

The seeds form an article of export to China, where they are known as "ta-fung-chi." While in Hongkong the writer inquired about ta-fung-chi and found them on sale in native Chinese drug stores at \$20 for 100 pounds. Since only about 32 per cent of the seed is kernel, the price is rather high.

HYDNOCARPUS CASTANEA.⁶

While in search of *Taraktogenos kurzii* near the Siamese border but in the Burmese territory, the writer came across a species belonging either to *Hydnocarpus* or to *Taraktogenos*. It grew in a dense rain forest, on steep, densely wooded slopes, near the jungle village of Thinganyinon. Unfortunately, the tree was not in flower, but it had immature fruits, a comparison of which with those of *Taraktogenos kurzii* rendered doubtful its identity with that species. The time of flowering is in April, and the fruits ripen in July. The writer's visit was in December.

Having known that *Taraktogenos kurzii* was said to occur in the Martaban Hills, the writer inquired, on reaching Moulmein on December 24, 1920, whether anyone had seen kalaw trees anywhere in the Martaban Hills. A Mr. Shwaloo, the son of a Burmese physician, stated that he knew where there were thousands of kalaw trees. Arrangements were made to explore the Martaban Hills, and a party, consisting of the writer, Mr. Shwaloo, a cook, and a boy, left for Martaban station and thence by rail for Paung. From Paung the party proceeded by bullock cart to Oktada, a small village at the foot of the Kalama Range. The same evening the writer followed the steep dry creek bed, strewn and lined with enormous boulders of quartz rock, to the Mondo Range. In the crevices be-

⁶ *Hydnocarpus castanea* Hook. f. and Thoms. (12, p. 197). Specimens collected by the writer are deposited in the United States National Herbarium: Rock No. 744, U. S. N. H. Nos. 1,090,008 and 1,090,009.



THE SIAMESE "MAIKRABAO" TREE, *HYDNOCARPUS ANTHELMINTHICA* PIERRE.

Growing along a klong or estuary near Ladbunakao in eastern Siam. The tree to the left and the tree behind the man are both *Hydnocarpus anthelmintica*. (Photographed by J. F. Rock, November 20, 1920; P25505F8.)



FRUITS OF THE SIAMESE "MAIKRABAO" TREE, *HYDNOCARPUS ANTHELMINTHICA* PIERRE.

The fruits are pinned against the trunk of a maikrabao tree growing near Klong Sarn, Bangkok, Siam. (Photographed by J. F. Rock, November, 1920; P22627FS.)

tween these enormous boulders, often 10 feet high or more, there grew in great abundance a tree which was loaded with young fruits, then the size of a tennis ball and covered with a fawn-colored tomentum. The natives stated that when the fruits matured they became much darker. The trees observed had a height of about 80 to 90 feet and their size was much greater in every respect than that accredited to *Taraktogenos kurzii*.

The ridge immediately back of Oktada, known as "Taguwee" (white-sand stream), was explored the following day. Taguwee is a lower chain of the main Kalama Range, the backbone of the Martaban Hills. The slopes are here very steep, and the soil is a quartz sand in which are embedded huge smooth boulders which reach a height of 15 to 20 feet. The forests are here composed of Dipterocarpus, Shorea, and certain Euphorbiaceæ, but mainly of *Hydnocarpus castanea*, which here develops trunks 2 feet in diameter and having a height of 80 to 90 or even 100 feet. The tallest grew in a depression near a watercourse, at that time with running water which a little lower down formed quite a waterfall. The undergrowth of these Hydnocarpus forests is mainly a fern, *Polybotrya helferiana* Kunze.

The other plant associates of Hydnocarpus in these localities are certain Rhamnaceæ, Pinanga palms, and Plectocomia; Caryota occurs lower down, as does Lagerstroemia, Bauhinia, Millettia, *Cassia tora*, Smilax, Jasminum, and species of Euphorbiaceæ, Annonaceæ, and Araliaceæ. The approach to the kalaw (*Hydnocarpus castanea*) forests led through a jungle of a peculiar, broad-leaved, procumbent bamboo, called wanue, often also written wanway (*Dinochloa maclellandii*). This bamboo covers the lower hillside in dense stands, through which the natives make regular tunnels. It was here that fresh tiger tracks were encountered, which led through this dense bamboo jungle and the kalaw forest to the top of the ridge.

In the lowlands at the foot of the hills the natives have plantations of durian (*Durio zibethinus*) and *Sandoricum indicum*, which, by the way, apparently grows wild. *Blumea balsamifera* is one of the most common weeds there.

The seeds of these kalaw trees are collected by natives, who take out licenses from the forest office in Moulmein for that purpose. None of the seeds of this region are sold to Europeans, but are immediately disposed of to native vendors in the bazaars. Much of the seed, however, is lost, as the collectors do not take the fruits from the trees when ripe but wait till they drop, a much less troublesome way to collect them. Moreover, monkeys are fond of the fruit flesh and attack the fruits on the trees, dropping the seeds to the ground; and

many of the seeds are lost in crevices between the innumerable rocks and boulders. Porcupines also devour the seeds, and the result is that in all probability about 50 per cent of the crop is lost.

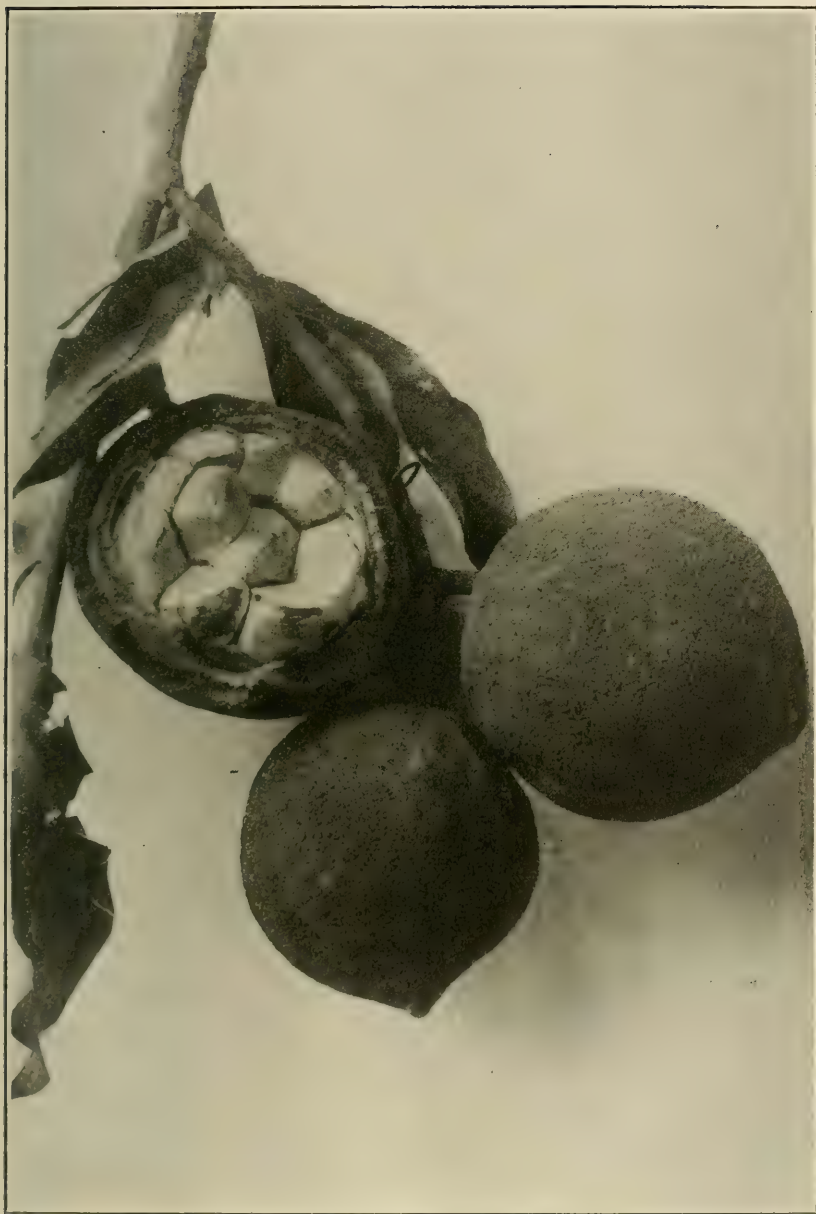
The trees are not regular fruiters. Those found in pure sand at an elevation of about 2,000 feet, the tallest and handsomest forming large forest tracts, were without fruit. In all, only two single small fruits were observed. The natives said that the year previous they had a very large crop. They will probably not get another crop from that particular locality before 1923. It was found that trees exposed to sunlight, standing by themselves in exposed locations, were loaded with immature fruits while, as has been said, those found in pure stands were without a vestige of fruit. After a search of several days one single tall tree was encountered under which ripe seeds were found with some of the fruit flesh still adhering; on the party's approach a troop of monkeys made its escape. This tree furnished about 170 mature fruits, each fruit containing from 20 to 30 large angular seeds (Pl. III). The fruits are quite different from those of *Taraktogenos kurzii*; they are the size of an orange, pointed at the apex, dark brown, granular, and rough, while those of *T. kurzii* are perfectly globose, velvety tomentose, and fawn colored. The seeds are much alike. *Hydnocarpus castanea* seeds take twice as long to germinate as do those of *Taraktogenos kurzii*, probably because of their double testa.

Many of the trees were found to have pieces of bark cut off their trunk, and, on inquiry, the writer was told that the bark is boiled and the decoction drunk as tea for internal disorders, as well as for skin diseases. The larger trees have strings tied around their trunks, so that they may easily be identified by children and young men sent into the forests to cut the bark. The illustration here presented (Pl. IV) shows the trunk of a large *Hydnocarpus castanea* tree with a string made out of bamboo tied around the trunk. It also shows how much of the trunk had been decorticated. Decortication is soon followed by white ant, or termite, attacks, which make short work of these trees.

HYDNOCARPUS CURTISII⁷

This species was collected by the writer on the island of Penang, in the jungle along the only waterfall on the island. It is a small tree 15 feet high, or rarely taller. The fruits, which are rather small, are about an inch in diameter and globose. No chemical examination has yet been made of the oil from seeds of this species. The writer found only male flowers and no fruits (March, 1921).

⁷ *Hydnocarpus curtisii* King (13; p. 119). Specimens collected by the writer, are deposited in the United State National Herbarium: Rock No. 1188, U. S. N. H. Nos. 1,090,025 and 1,090,026.



FRUITS OF *HYDNOCARPUS CASTANEA* HOOK. F. AND THOMS.

Note the closely packed seeds in fruits collected in the Martaban Hills, Burma. (Photographed by J. F. Rock, January 9, 1921; P27065 FS.)



TRUNK OF *HYDNOCARPUS CASTANEA* HOOK. F. AND THOMS.

The bark of this tree is used by the natives in the form of a tea for internal disorders and skin diseases. The string tied around the trunk enables it to be identified by the children and young men who collect the bark. Although the seeds of this species are collected and sold in the bazaars of Burma, nothing is as yet known regarding the composition of their fatty oil. The tree shown was growing in the Martaban Hills, Kalama Range, Burma. (Photographed by J. F. Rock, January 9, 1921; P27063FS.)

TARAKTOGENOS KURZII.^s

Taraktogenos kurzii was described by Sir George King from specimens collected by S. Kurz in Pegu Toukyeghat, Burma. These specimens had been erroneously identified by Kurz as *Hydnocarpus heterophylla* Blume (*Taraktogenos blumei* Hassk.), a species occurring in Java. There are three sheets of Kurz's specimens in the Calcutta Herbarium, two of No. 532 from Pegu Toukyeghat and another, No. 1822, from Pegu Chonuymenah. There are no recent collections of this species, unless one recognizes as *Taraktogenos kurzii* the Thinganyinon plant⁹ from Lower Burma, collected by Dr. I. H. Burkill, now of Singapore. This, to the writer's mind, is not permissible, owing to the difference in the fruits.

It was the writer's object to locate *Taraktogenos kurzii* in its native habitat and to look up especially all those localities from which Taraktogenos seeds are brought to European chemists in India, in order to ascertain whether or not the seeds they are using are those of this species. *Taraktogenos kurzii* is evidently widely distributed in Burma. Numerous localities were given where kalaw trees may be found, as, for example, in Burma, at Chongnakwa, Lower Burma, and also at Tabyo. These places can be reached from Moulmein by way of Kyain or Metan. These regions belong to the Attaran division. Whether the trees found are the true *Taraktogenos kurzii* or not is an unsettled question, as material from these localities is not known, save seeds collected by natives. It is very likely that they represent *Hydnocarpus castanea*.

The writer was informed by the Rangoon forest office that the true species was found in the upper Chindwin district, and especially in the neighborhood of Mawlaik. To reach Mawlaik it is necessary to go by train to Myonhaung, where another train is taken to Amarapura, on the shore of the Irrawaddy, only a few miles from Mandalay; thence by ferry across the Irrawaddy to Sagaing and by train to Monywa, on the upper Chindwin River. It is supposed that *Taraktogenos kurzii* can be found even near Mandalay and lower down in the forests of Pegu; in fact, the latter place is the type locality, where Kurz collected his original specimens. From Monywa a stern-wheeler requires four days to reach Mawlaik. This latter locality the writer visited. The Chindwin is a very winding river and in the winter navigation is very difficult, owing to the shallowness of the water and the constant changes of the channel.

^s *Taraktogenos kurzii* King (13; p. 123). Specimens collected by the writer are deposited in the United States National Herbarium: Rock No. 802, U. S. N. H. No. 1,090,010; Rock No. 814, U. S. N. H. Nos. 1,090,011 to 1,090,014; Rock No. 897, U. S. N. H. Nos. 1,090,019 to 1,090,021.

⁹ Specimens were also collected by the writer and are deposited in the United States National Herbarium: Rock No. 694, U. S. N. H. Nos. 1,090,005 to 1,090,007.

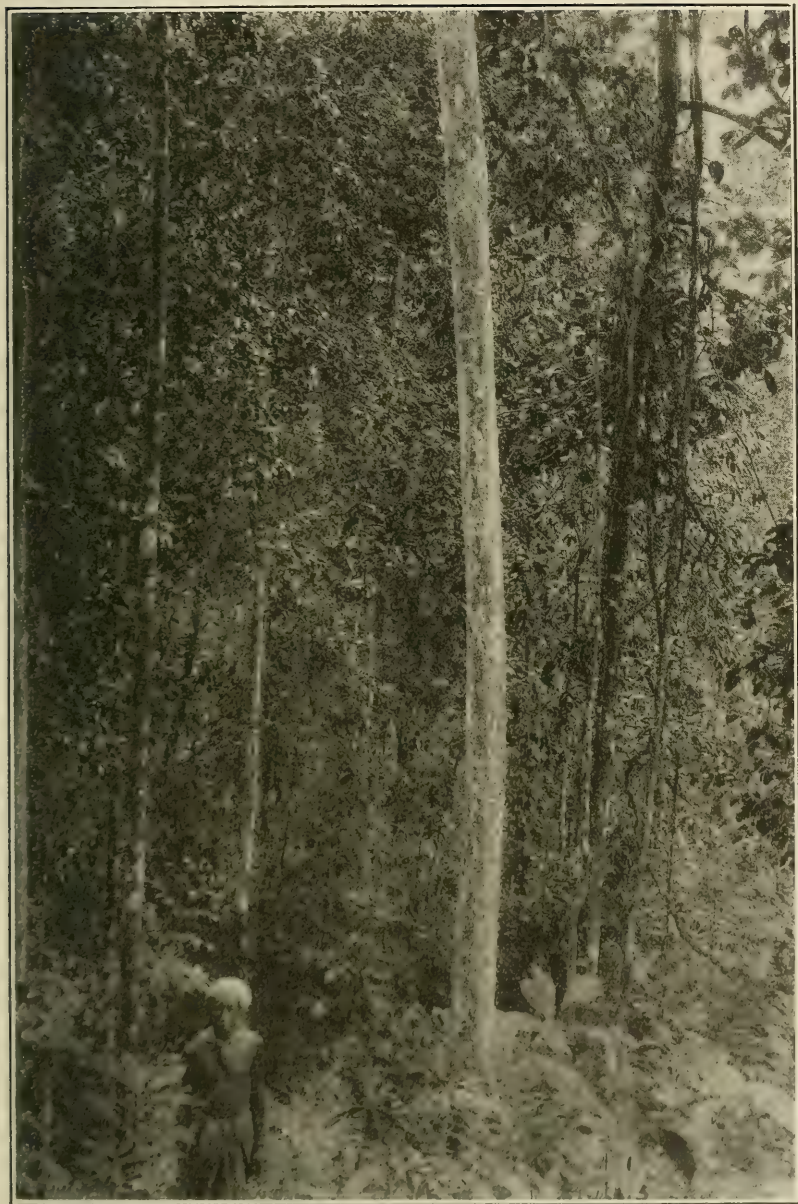
The first definite information regarding the presence of kalaw trees in the neighborhood was obtained at Maukkadaw. It was reported that the trees grow plentifully but in restricted areas some 20 miles from Maukkadaw, at Chingyon Ohndon, district of Kyongyi, in the Hkaungdan forest. Lack of time prevented the writer from investigating these forests on the upward journey. However, seedlings were secured from this region on the return journey to Rangoon. Of these seedlings one reached Hawaii in good condition and is now flourishing.

On arrival at Mawlaik, the writer called at the forest office and received the following information:

The presence of *Taraktogenos kurzii* is known to us only through natives who take out licenses for collecting the seeds, after the rainy season, in three localities.

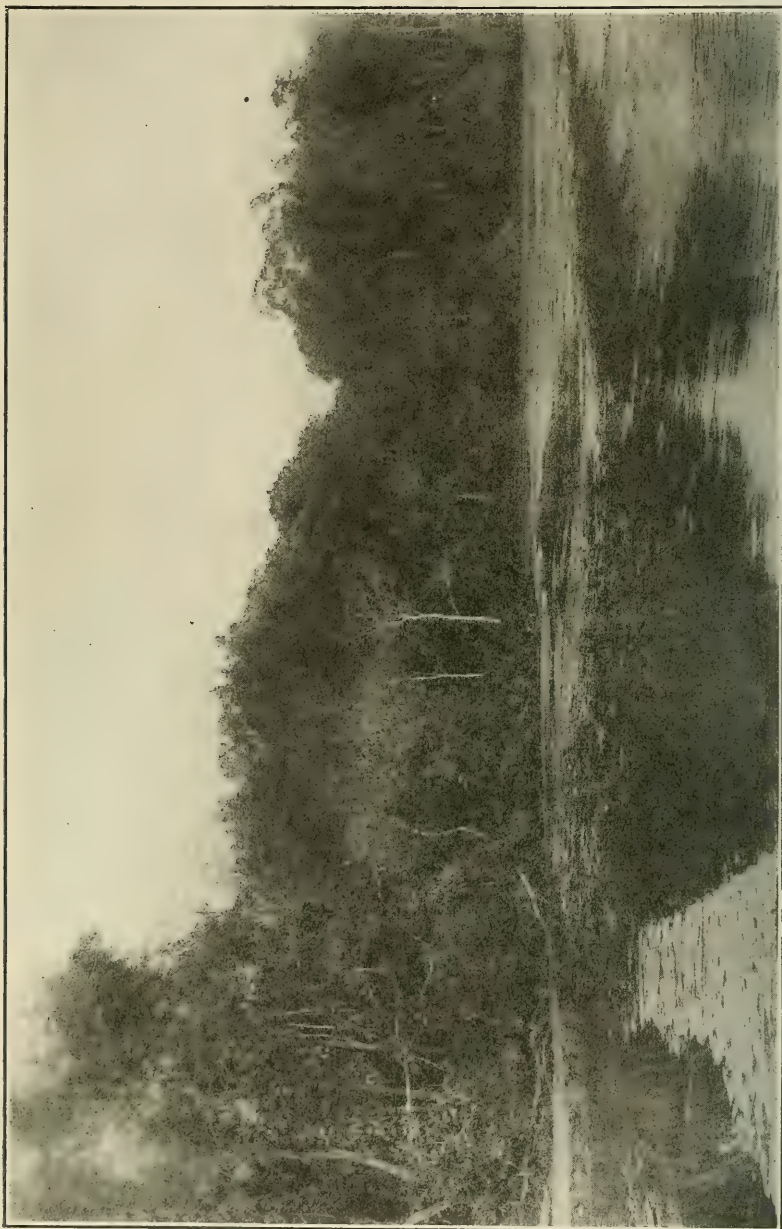
These localities are at Maingyaung, some 50 miles from Mawlaik, and at Khoung Kyew and Kyokta on the Khodan (or Khodaun) stream. The writer engaged a dugout canoe and with a cook, a boy, and an interpreter followed the Chindwin in its downward course as far as Chaing (Kyaing), whence the overland journey through dense forests commenced, first to Nansouksouk and thence to Thoung Dwin; the next stop was at Khoung Kyew. This is a small village situated on a bend of the Khodan stream, facing dense forests on the opposite bank. The soil consists largely of quartz sand, save in the flatlands, which are of clay or rather loamy and inundated during the rainy season, which extends from May to October. The river bottom is all sand and not a single rock is encountered anywhere. After Thoung Dwin the land is undulating and somewhat hilly, but no high elevation is reached. The forest is very dense and has a forbidding appearance. It is composed of *Cephalostachyum pergracile*, *Ficus* spp., *Garcinia* spp., *Terminalia* spp., *Quercus* spp., and various Dipterocarpaceæ, Euphorbiaceæ, Meliaceæ, and Leguminosæ. The undergrowth is formed of ferns, *Clerodendron* spp., various Acanthaceæ, etc.

At Khoung Kyew the headman, or tajee, of the village, several coolies, the interpreter, and the writer started out in search of kalaw trees. Two localities were visited, one by following a narrow creek bed with running water. Here the trees were very tall, some 50 to 60 feet. *Taraktogenos kurzii* covered the steep hillsides, which were pure grayish loamy quartz sand. Some trees were actually growing in the stream bed. The whole area supporting the kalaw trees was very small and was restricted to about 30 or 40 acres. It was a dense tropical and humid forest, though very cool at this time of the year (January, 1921). There were many climbers, such as *Thunbergia laurifolia*, while the undershrub was composed, especially along the stream bed, of an acanthaceous species (*Phlogacan-*



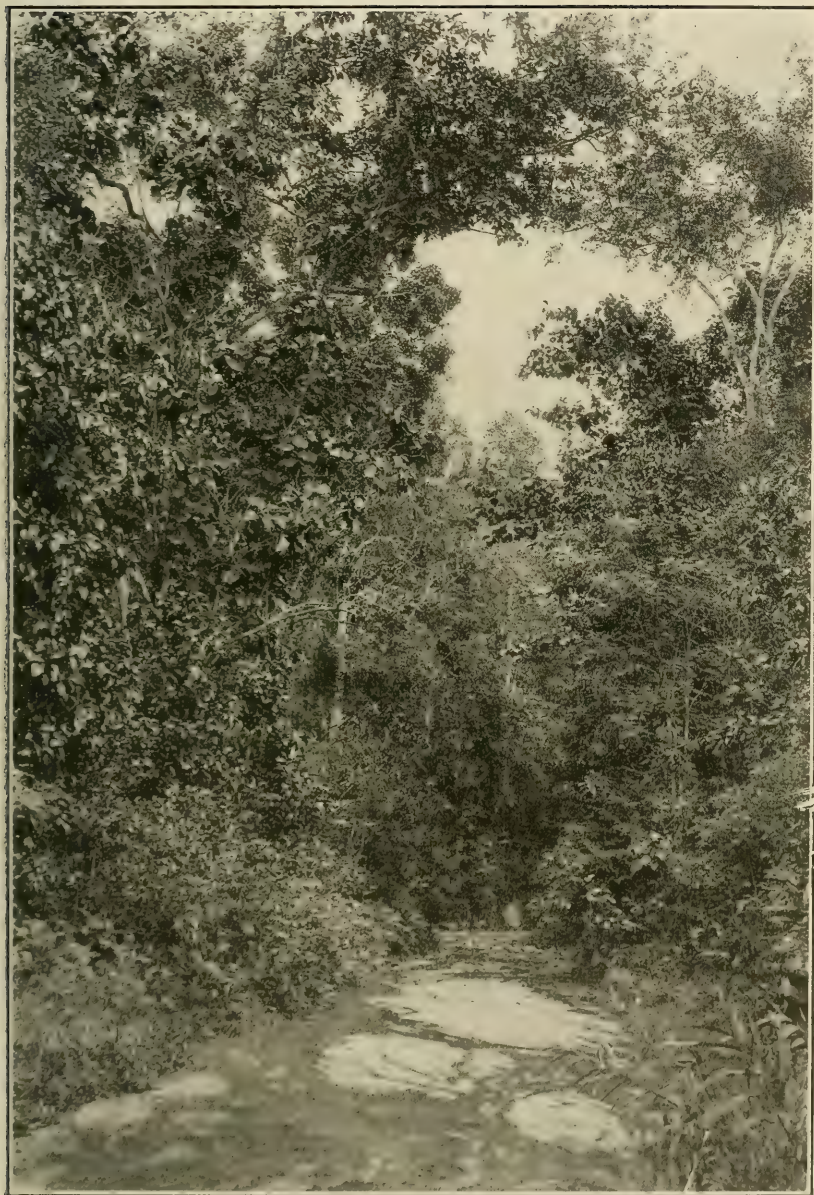
PURE STAND OF THE GENUINE CHAULMOOGRA TREE, TARAKTOGENOS
KURZII KING.

Trees growing in the forest near the jungle village of Khoung Kyow, Upper Chindwin district,
Northwest Burma. (Photographed by J. F. Rock, January 20, 1921; P22818FS.)



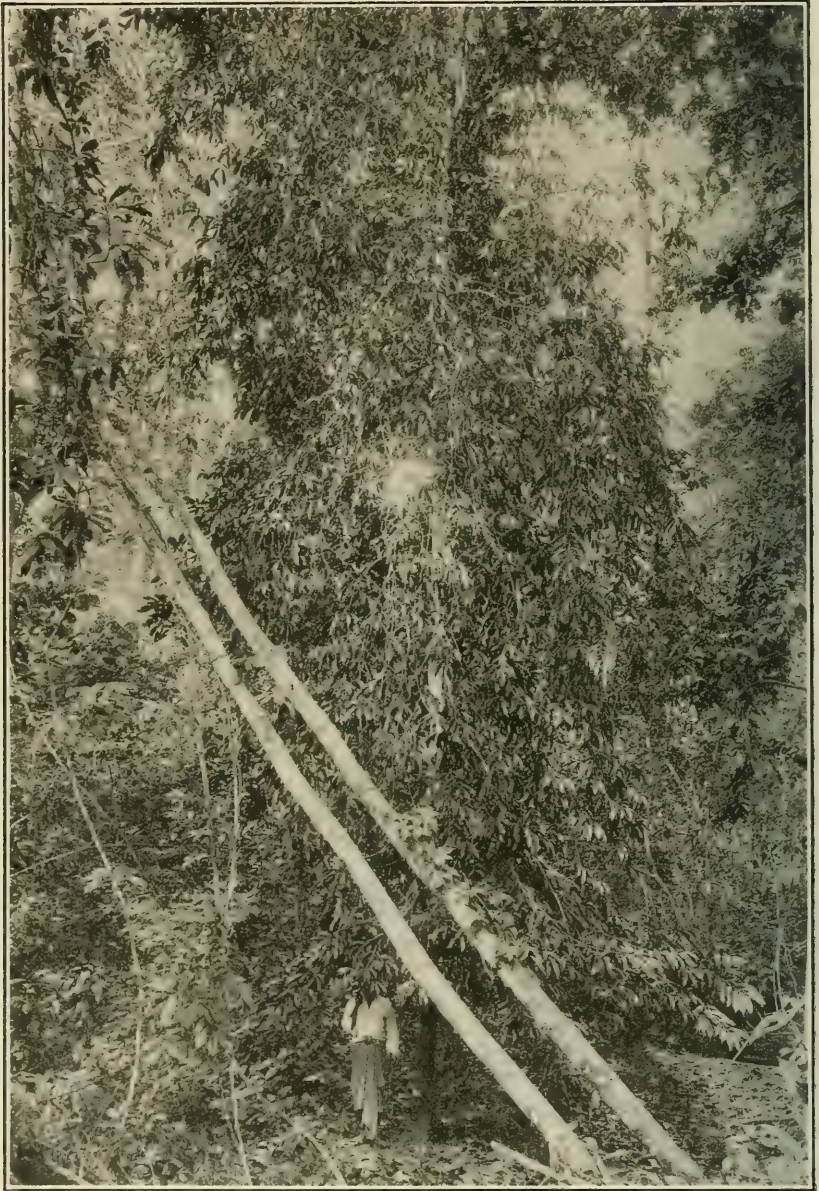
THE KHODAN STREAM, A TRIBUTARY OF THE UPPER CHINDWIN.

Scene near the jungle village of Kyokta, Northwest Burma. It is along creek beds opening into this stream that *Taradogenos kurzii* occurs. (Photographed by J. F. Rock, January 21, 1921, F2277FS.)



AICREEK BED LEADING INTO CHAULMOOGRA FORESTS.

Scene near the jungle village of Kyokta, Upper Chindwin district, Northwest Burma. (Photographed by J. F. Rock, January 21, 1921; P22776FS.)



A GENUINE CHAULMOOGRA TREE, TARAKTOGENOS KURZII KING.

Note the peculiar pendent branching habit of this species, growing along a creek bed near the jungle village of Khoung Kyew, Upper Chindwin district, Northwest Burma. (Photographed, by J. F. Rock, January 20, 1921; P22767FS.)



FRUITS AND LEAVES OF THE GENUINE CHAULMOOGRA TREE, TARAKTOENOS KURZII KING.

One fruit is cut in half to show the seeds. (Photographed by J. F. Rock, near Kyokta, January 21, 1921; 122725FS.)



FRUITING BRANCH OF THE GENUINE CHAULMOOGRA TREE, TARAKTOGENOS
KURZII KING.

From a tree growing in the jungles near Khoang Kyew, Northwest Burma, showing the trunk
and smooth bark of the species. (Photographed by J. F. Rock, January 20, 1921; P22768FS.)

thus pubinervius). In the Taraktogenos forest proper a fern (*Polybotrya hamiltoniana* Presl) form the main undergrowth on the sandy soil.

The second locality was on the opposite bank of the Khodan stream near a broad bend. The banks were a solid wall of green, being at first flat and covered with huge trees of *Dipterocarpus alatus* and *Ficus* sp., *Strychnos nux-vomica*, *Quercus* spp., and *Mangifera caloneura*. This forest is known as the Thadunphue. The undergrowth was again *Polybotrya hamiltoniana*; also *Wallichia caryotoides*, a soboliferous palm. The ground rose rather steeply after passing through dense bamboo jungle. The creek beds were very deep, the water evidently finding it very easy to cut deep channels through these sandy hills. Taraktogenos formed here pure stands (Pl. V), while near the top of these hills grass with *Wallichia disticha* was the dominant feature. *Calamus tenuis* is also very common in the kalaw forests, as is a *Pandanus* with very slender leaves (probably *P. furcatus* Roxb.) and a species of *Pteris*.

Only a very few seeds were secured at Khoun Kyew, and on that account the writer proceeded to Kyokta. After crossing the Khodan stream (Pl. VI) many times and walking barefooted for many miles through the dense and somber forests, the party, consisting of about fifteen coolies and the others previously mentioned, arrived at Kyokta, a lonely jungle village of about thirty houses. A Taraktogenos forest does not occur in the immediate neighborhood, but about 5 miles distant from Kyokta. The only way to approach these forests, mainly composed of *Taraktogenos kurzii*, is by following a creek bed (Pl. VII), which is dry in the winter. The trees first encountered are *Dipterocarpus alatus*, *Cephalostachyum pergracile*, a grove of bamboo, species of *Ficus*, *Quercus*, *Mezoneurum*, *Dalbergia*, *Meliaceæ*, etc. The banks of the sandy creek bed become steeper and finally are clothed altogether with *Taraktogenos kurzii*. The undergrowth again is *Polybotrya hamiltoniana* Presl, a sand-loving fern. The bark of the kalaw trees is smooth, pale yellowish brown; the trunks are straight; the branches, which appear quite low down, are at right angles to the trunk, but droop downward, giving the trees a pyramidal shape and the aspect of an old *Abies* or fir. (Pl. VIII.) The fruits, which are perfectly round and not pointed at the apex, are the size of a large orange, of a light fawn color and velvety tomentose. (Pl. IX.) They are on short, thickened peduncles and are borne on the ends of the flexible branches which become pendent owing to the weight of the fruits. (Pl. X.) Unfortunately, there were no mature fruits to be found on any of the trees, but a quantity of seeds, which either had escaped the vigi-

lance of the seed collectors or were from fruits which had ripened later, were found on the ground.

It was very evident from observations as well as from the statements of the natives that *Taraktogenos kurzii* produces fruits irregularly. A heavy crop is followed by two years of poor fruiting, while the next year following a large crop can again be expected. The natives stated that they go into these forests to collect the seeds only about once in three years, and then only in the months of October and November. The fruits, like those of other species of *Taraktogenos* and *Hydnocarpus*, mature during the rainy season, which is from May to September; they then drop to the ground, being assisted by numerous monkeys. Bears are also very fond of the fruit flesh, and large numbers of them roam the forests in search of kalaw fruits. Therefore, at that particular time, the natives refrain from going to collect these, as they have no firearms and their spears are inadequate weapons with which to meet a horde of bears. The heavy rains wash the large and often buoyant seeds into the creek and thence into the Khodan stream, the fish of which feed on them. The natives stated that they dare not eat any fish from the Khodan stream, as it would produce the same effect as the eating of a number of fresh kalaw seeds. Wild pigs are also fond of the seeds, and the natives refrain from eating pork at the kalaw fruiting seasons, as the flesh of pigs which have fed on kalaw seeds is poisonous, producing nausea and vomiting. After the rains have ceased, when the animals have had their share of kalaw fruits and seeds and the heavy rains have washed large numbers of them into the stream, the natives proceed, in parties of 20 to 30, to collect the remaining seeds. Needless to say, they lose about 50 per cent or more of each crop through the causes just enumerated.

The writer found many seeds germinating on the edges of the creek bed and in the pure sand of these dark and somber hill forests where the sun can hardly penetrate. A number of these seedlings get established sufficiently to withstand the heavy downpours which must swell these creeks to a considerable extent; for only short periods, however, as the sandy soil takes up a great volume of these rushing torrents. Large kalaw trees have been found by the writer growing in the middle of these beds. *Taraktogenos kurzii* develops a strong and vigorous taproot, which enables the tree to withstand strong currents. That the currents are swift was made evident by the exposure of the whole root system of an enormous tree of *Dipterocarpus alatus* which grew on the steep banks of the creek.

The collection of seed, even in the winter, is exceedingly dangerous, owing to wild animals, especially tigers and elephants. The cold season being the mating season, these animals roam through

the forests. Tigers wreak havoc in these jungle villages by carrying off bullocks, and often, as was the case during the writer's visit at Kyokta, human beings. A tiger followed the writer and 31 coolies in broad daylight for a whole day up the creek bed into the kalaw forests. Returning during the following night, the beast killed three women and a 2-year-old child.

All the seed available was collected by the writer and packed in moist powdered charcoal in cotton bags. These were wrapped securely in strong oil paper, then in heavy manila wrapping paper, securely tied, and dispatched from Mawlaik to Honolulu, Washington, D. C., the Philippines, and Singapore. The seeds sent to Honolulu and Washington arrived in good condition and germinated well in both places, the result being several thousand trees which give promise of becoming well established.

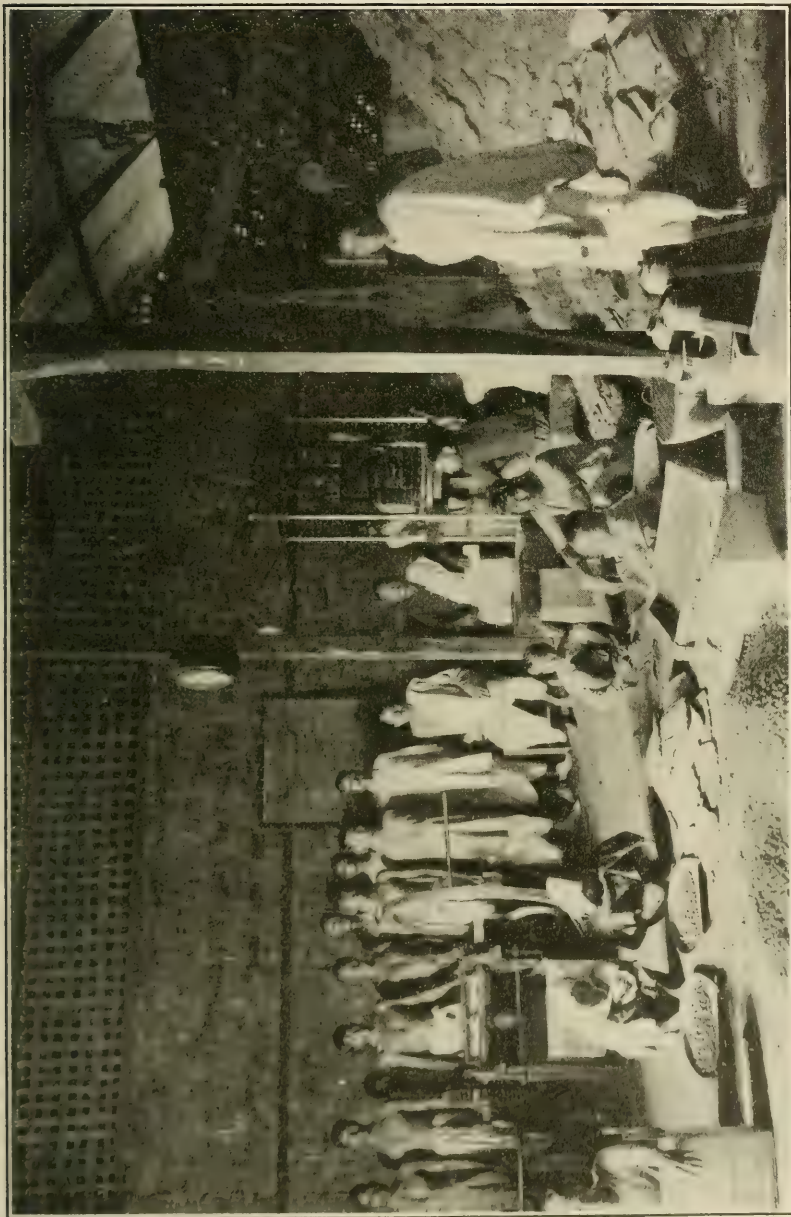
The writer then returned to Rangoon and thence went to Calcutta, where he studied the type material of *Hydnocarpus* and *Taraktogenos* in the Sibpur Herbarium. These types, together with a number of new and undescribed species found in the collection, were photographed and copious notes taken. Drug firms, such as Smith, Stanistreet & Co. and Glen & Co., were visited. The former were using mainly *Hydnocarpus wightiana* seeds to obtain the oil from which they prepared the ethyl esters used by Dr. Muir for the treatment of lepers in the leprosy station of the Calcutta School of Tropical Medicine. Smith, Stanistreet & Co. stated that most of their seed of *Taraktogenos kurzii* was obtained from near Dibrugarh, in northeastern Assam.

Dr. Muir accompanied the writer to Dibrugarh by way of Tinsukia. At the forest office in Dibrugarh, the writer was informed that the Dibru forests contained scattered trees of *Taraktogenos kurzii* as well as of *Gynocardia odorata*. Arrangements were made with the forest office, and accompanied by a very able forest ranger, courteously provided by the main office at Shillong, the writer went to Tinsukia by rail and thence walked to Rangagora and beyond to the forest bungalow on the Dibru River. The following day the Dibru forest reserve was explored for *Taraktogenos kurzii*. This forest reserve is marked as the eighth in the Lakhimpur district and is situated between the Brahmaputra and the Dibru Rivers at between 27° 36' and 27° 42' north latitude and 95° 15' and 95° 31' east longitude. The land is rather flat here, and during the rainy season is inundated, so that walking through it is impossible. The soil is not quartz sand, but loamy and much heavier and evidently somewhat impervious. In certain stretches, especially along the trail, it is quite swampy, and these stretches were full of circular depressions with standing water, the tracks of wild elephants.

On examination of fruiting specimens it appeared that the species said to be *Taraktogenos kurzii* differed somewhat from the upper Chindwin species. The fruits were distinctly ridged, especially toward the apex, a character absent in the specimens from Burma; they were also darker in color. Unfortunately, no flowering trees could be found, and some of the trees had semimature fruits but no ripe fruits whatever. It was again stated that July and August were the fruiting season. As is not the case in Upper Burma, the trees here (which may be *Taraktogenos kurzii*, but concerning which there still remains some doubt, owing to the characters mentioned above and the absence of flowers) grew as scattered individuals save in one locality, where they covered an area of perhaps half an acre and formed about 80 per cent of the tree growth. The plant associates of this doubtfully determined *Taraktogenos kurzii* in the Dibru forest are mainly *Artocarpus chaplasha*, a valuable timber tree which seeds in August, *Dillenia indica*, *Cinnamomum* sp., *Pterospermum acerifolium*, *Myristica* sp., *Ficus* sp., *Ficus elastica*, *Elaeocarpus* sp., aroids, a species of *Calamus* which climbs over the trees, etc. The tree here is known as lemtam, and the Burmese vernacular name kalaw is unknown in Assam. *Gynocardia odorata*, which is also known as lemtam in Assam, is found in company with this species of *Taraktogenos* in the Dibru forest, but it is rather scarce. No seeds were obtained of the supposed *Taraktogenos kurzii* of the Assam Dibru forest, but seedlings from this forest, which arrived in good condition in Hawaii, were left in charge of Dr. H. L. Lyon, collaborator of the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry.

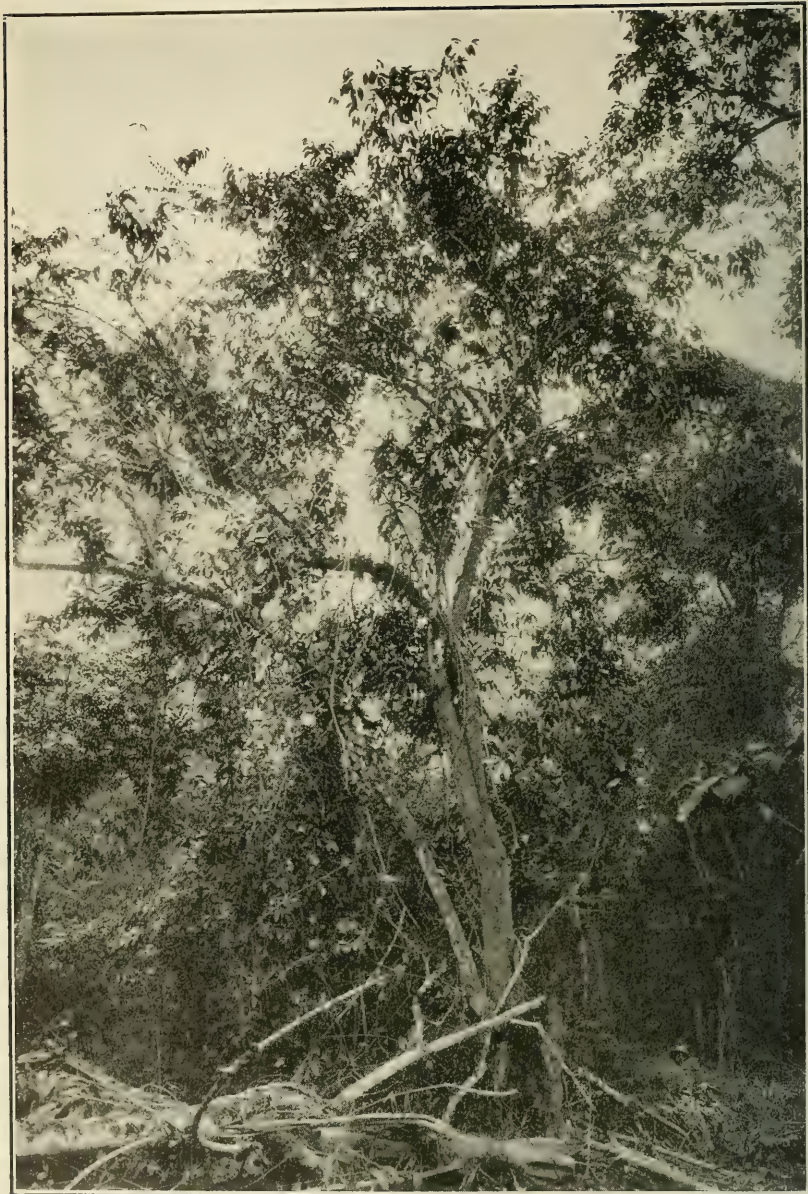
Besides occurring in the Dibru forests, *Taraktogenos kurzii* is said to grow near Bargpathar on the Dhansiri River in the district of Sibsagar, a subdivision of Golaghat; also at Jamugri in the same subdivision, but on the Doyang River, and all over the district of Mowgong near Silghat, Assam. *Shorea robusta*, the famous sal tree of India and Assam, is very common in the Lakhimpur district of northern Assam and is an indicator of the absence of *Taraktogenos kurzii*; wherever the latter occurs the former is absent, and vice versa.

On the writer's return to Calcutta, he stopped at Chittagong in Lower Bengal, whither he was directed by the manager of Glen & Co., dealers in chaulmoogra oil in Calcutta. Chaulmoogra oil is here manufactured by a Bengal firm, Prasana Kumar Sen. The writer, in company with Dr. E. Muir, visited Mr. Sen's establishment and examined the seeds from which he obtains chaulmoogra oil. They were indeed those of *Taraktogenos kurzii*. The extraction of chaulmoogra oil as carried on at Mr. Sen's establishment is a very simple process (Pl. XI). The seeds when they arrive from the forests are



CHAULMOOGRA-OIL FACTORY OF PRASANA KUMAR SEN, CHITTAGONG, LOWER BENGAL.

(Photographed by J. F. Rock, February, 1921; P22731FS.)



THE FALSE CHAULMOOGRA TREE, *GYNOCARDIA ODORATA* R. BR.

This tree was growing in the Berjan forest reserve near Rangagora, Assam, India. (Photographed by J. F. Rock, February, 1921; F22730FS.)

carefully washed, after which they are dried in the sun for one or two days, then shelled by coolie women, sorted, and placed between corrugated rollers worked by a hand crank, where they are crushed. They are then placed to a thickness of about an inch in jute bags about a foot square. Five layers of eight bags each are pressed at one time. A steel plate is placed above each layer and the whole submitted to hydraulic pressure. The cold-drawn oil is collected in tin cans and filtered through ordinary blotting paper. The resulting press cake, still rich in oil, contains 6 per cent of nitrogen and is sold as manure to tea planters and to paddy-field owners. Mr. Sen complained of the difficulty of obtaining *Taraktogenos kurzii* seeds. He said that often he had to advance money two years ahead to the jungle people in order to obtain an adequate supply of seeds to keep his concern going.

Taraktogenos kurzii is apparently very common in the Chittagong hill tracts and according to the forest office of Chittagong occurs in the Kassalong forest reserve. This reserve is reached in the following manner: A steam launch plies once a week between Chittagong and Rangamati on the Karnaphuli River, a journey of three days; from Rangamati a dugout canoe has to be employed as far as Mainimukh, a journey of about 7 to 10 days to the edge of the Kassalong reserve. The trees occur throughout the hill tracts, but in isolated circumscribed areas. It is from this region, infested with tigers, panthers, leopards, and wild elephants, that most of the chaulmoogra seeds come to the Indian markets and to dealers in chaulmoogra oil. Owing to lack of time and to threatened railroad strikes, the writer was unable to explore the Kassalong forests. As in any case it would have been too early in the year (February, 1921), the fruiting season being in July and August, the trip was abandoned.

It may be of interest to state that certain fish of the Kassalong River, similar to those of the Khodan stream, feed on the seeds of *Taraktogenos kurzii* and when killed and eaten produce the same effect as would a large dose of chaulmoogra oil. The species of fish which is especially fond of chaulmoogra seed is said to be the mirghamahar (*Cirrhitina mirgha*), and they are on that account absolutely avoided. In Assam the natives made a similar statement to the writer, but it involved a different species of fish, living in the Dibru River.

Other locations given for *Taraktogenos kurzii* by the Agricultural Ledger of India are: Tippera, South Sylhet, and the Lushai Hills in eastern Bengal and Assam; also Arakan Yomas, near Kan, at about 3,000 feet elevation, Mandalay, Pyinmana, Tharawadi, Hanthawadi, Shwegyin, Pegu, Amherst, and the Mergui Archipelago in Burma.

This tree is also said to occur on the Andaman Islands, and especially the South Island, in the Chouldari Hill jungle, and at Port Monat, as well as at Manpur and in the Dhanikari Hill jungles.

From the specimens examined in the Sibpur Herbarium, it is exceedingly doubtful whether the Andaman species belongs to *Taraktogenos kurzii*. It is quite possible (and the material in the Sibpur Herbarium would substantiate the belief) that what is said to be *Taraktogenos kurzii* in South or Lower Burma and that in the Andaman Islands are undescribed species belonging either to *Hydnocarpus* or to *Taraktogenos*. All the herbarium material in Calcutta of species belonging to this group is very fragmentary and does not permit an adequate description of the undescribed species present in the collection; nor does the material of the described species allow critical revision, flowers or fruits being absent in many instances.

ASTERIASTIGMA MACROCARPA.¹⁰

Asteriastigma macrocarpa was discovered by Beddome on his journey to Tinneveli and was first believed to be confined to Madras, where it is known as the cannon-ball tree. It is said that it has been found in Burma, but the writer has been unable to find specimens from that region either in the Economic Museum in Calcutta or in the main herbarium in the Sibpur Botanic Garden.

The fruits of *Asteriastigma macrocarpa*, as the specific name implies, are much larger than those of any *Hydnocarpus* or of *Taraktogenos kurzii*, though it greatly resembles those of the latter. The seeds are similar to those of *Taraktogenos kurzii*, but are considerably larger. Dr. Gosh, chemist for the Tropical School of Medicine of Calcutta, informed the writer that oil expressed from seeds of this species agrees well in its chemical composition and physical properties with that expressed from the seeds of *Taraktogenos kurzii*.

The *Asteriastigma* tree is a native of southern India and occurs in the native State of Travancore on the Ghat between Cottyam and Peermerd, at an elevation of 2,000 feet. It was impossible for the writer to visit this locality for various reasons, and consequently no seed was procured.

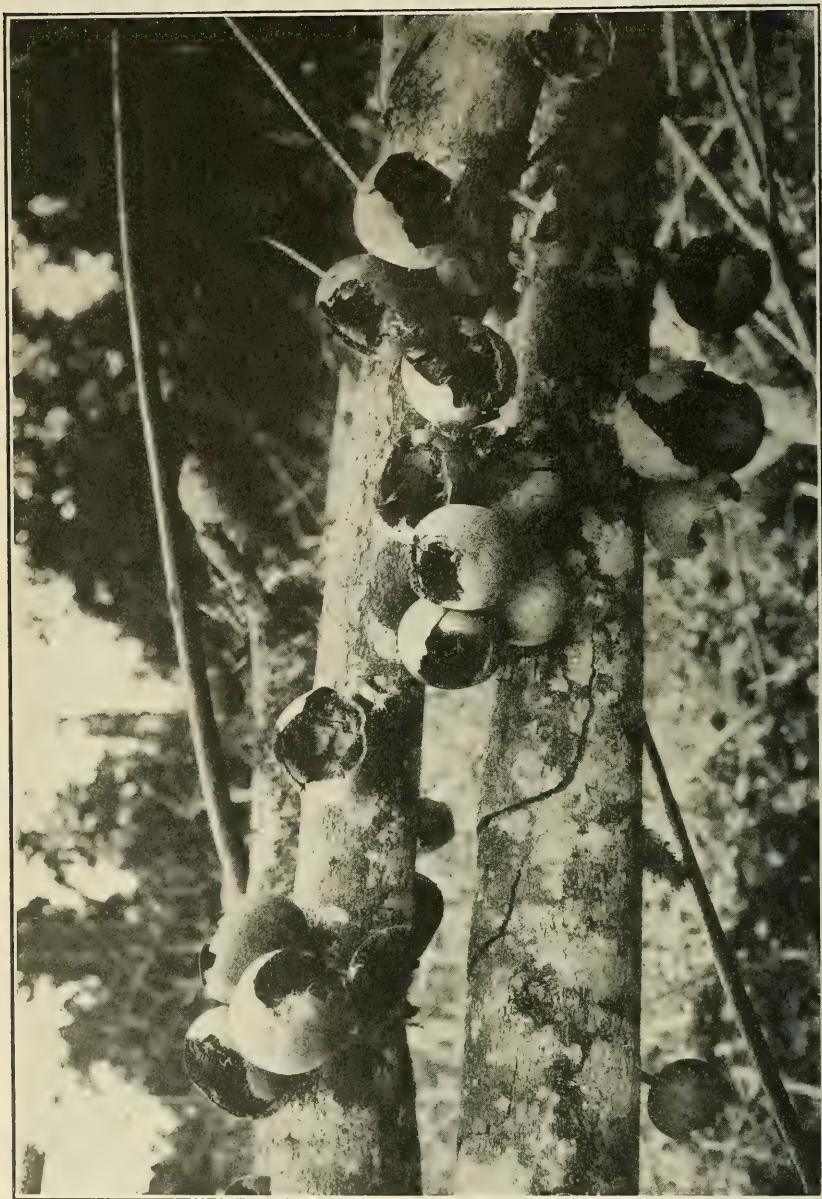
From the large size of the fruit (5 inches in diameter) and the larger seeds (the largest in the tribe, even exceeding those of *Taraktogenos kurzii*), it may perhaps be the best species to cultivate from a commercial standpoint; but no definite recommendation to that effect can be made until the species has been thoroughly investigated.

¹⁰ *Asteriastigma macrocarpa* Beddome (2, p. 236).



RIPE FRUITS OF THE FALSE CHAULMOOGRA TREE, *GYNOCARDIA ODORATA*
R. BR.

The fruits are pinned against a trunk of the same species, showing the lenticellate bark. Dibru forest reserve, Rangagora, Assam, India. (Photographed by J. F. Rock, February 20, 1921; P22722FS.)



FRUITS OF THE FALSE CHAULMOOGRA TREE, *GYNOCARDIA ODORATA* R. BR.

The fruits are borne on the trunks and main branches. Berjan forest reserve, near Rangagora, Assam, India. Monkeys are fond of the fruit flesh and open the fruits on the trees. (Photographed by J. F. Rock, February, 1921; P22726FS.)

GYNOCARDIA ODORATA.¹¹

Gynocardia odorata was first mentioned as *Chaulmoogra odorata* by Dr. William Roxburgh in his catalogue Hortus Bengalensis (22, p. 48) in 1815, but by name only. It was described as *Gynocardia odorata* four years later by Robert Brown. It was long considered to be the source of the true chaulmoogra oil. This species is a native of Sikkim, Assam, and Chittagong. It was observed by the writer between Siliguri and Darjiling along the Himalayan Railway up to an elevation of 4,000 feet; also in the Dibru and Berjan forest of northwestern Assam (Pl. XII). It is by far the most common tree in the Chittagong Hill tracts.

Gynocardia odorata is dioecious, and a number of trees must be planted together in order that fruits may be obtained.

It is known by the following native names: Sibi-turpu (Miri and Abor tribes), sibi-tulpi (Abor), tiki-sidik (Miri), taki-pomju-asing (Miri), takik-chagne (Duff), soh-pheeling (Khasi), chaulmoogra (in Bengal and Chittagong), and lemtam (in Assam). The Mikir names of what is possibly a second species of *Gynocardia* are thibong-kok and thibong-ko.

This tree is easily recognized even when not fruiting or flowering by the lenticellate trunk and by the foliage, which is oblong, with the petioles not thickened at the apex, as are those of *Taraktogenos kurzii*. Even in very young plants and, in fact, in freshly germinated seedlings, the lenticellate bark is noticeable. The fruits of *Gynocardia odorata* are borne on the trunk and on the main branches (Pl. XIII), while those of *Taraktogenos kurzii* are borne on the ends of the smaller branches. The seeds of *Gynocardia* are entirely different from those of *Taraktogenos kurzii*; the cotyledons are not foliaceous and have a lateral radicle instead of a basal one. The oil of *Gynocardia odorata* seeds is quite distinct from true chaulmoogra oil. It contains neither chaulmoogric nor hydnocarpic acid and is not optically active, as is the case with *Hydnocarpus* and *Taraktogenos* oils. The fruit flesh of *Gynocardia odorata* is of an entirely different consistency, being gelatinous, slimy, and powerfully fragrant. Monkeys are very fond of the flesh of this fruit, and it is exceedingly difficult to find mature fruits which have not been opened by them (Pl. XIV). Seeds of *Gynocardia odorata* were collected in the Dibru reserve and forwarded both to Hawaii and Washington, D. C., packed in a manner similar to those of *Taraktogenos kurzii* from Kyokta. They arrived in splendid condi-

¹¹ *Gynocardia odorata* R. Br. (23, p. 95). Specimens collected by the writer are deposited in the United States National Herbarium: Rock No. 875, U. S. N. H. No. 1,090,015; Rock No. 884, U. S. N. H. Nos. 1,090,016 to 1,090,018.

tion, having germinated on the way. On their receipt the seedlings were immediately transplanted into pots.

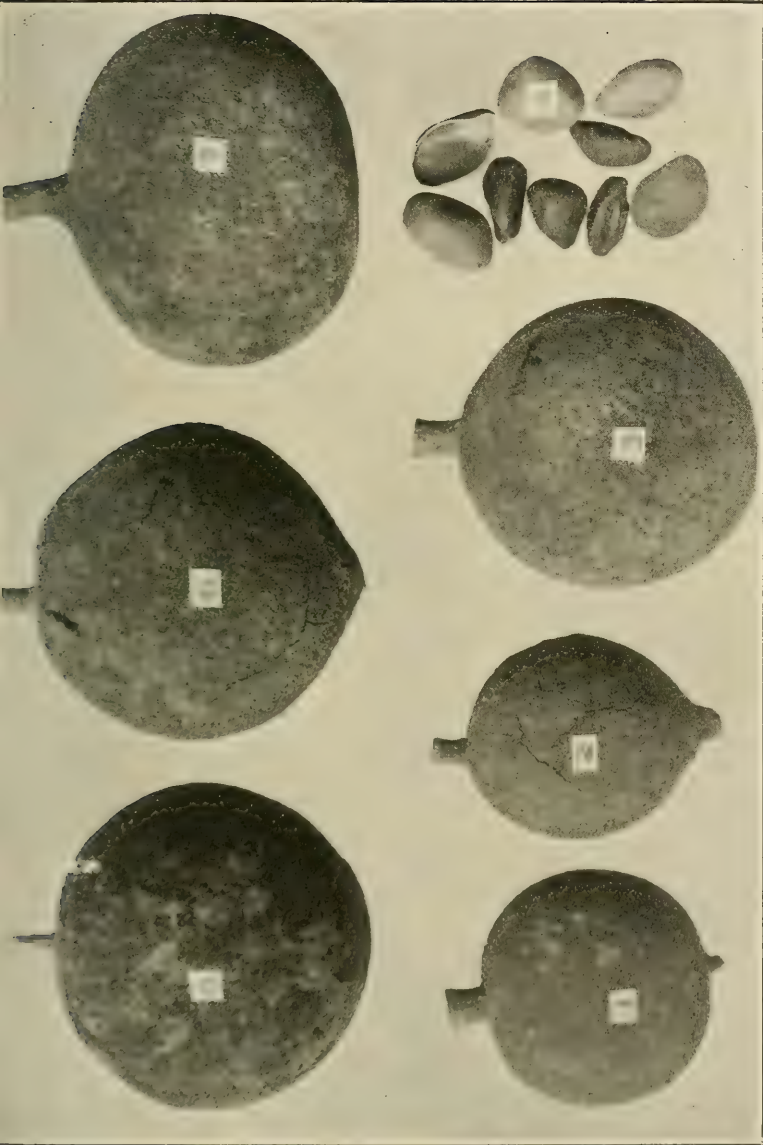
The Berjan forest reserve, situated near Rangagora, is devoid of *Taraktogenos kurzii*, but does contain *Gynocardia odorata*. The latter tree is associated with *Terminalia myriocarpa*, *Artocarpus chaplasha*, *Gmelina arborea*, *Cinnamomum cecidodaphne*, *Morus laevigata*, *Mesua ferrea*, *Bombax malabaricum*, *Canarium bengalense*, *Premna bengalensis*, *Myristica assamica*, *Ficus elastica*, *Kydia calycina*, *Macaranga indica*, *Heteropanax fragrans*, *Stereospermum chelonoides*, *Sterculia villosa*, and *Eugenia praecox*. Other trees growing here include *Terminalia bellerica*, *T. chebula*, and *T. foetidissima*.

The main tree in the forest of the Berjan reserve is a species of *Vatica*, which has as undergrowth young seedlings of the same species. The outskirts of and the approach to the Berjan forest reserve are mainly occupied by a tall timber bamboo, *Dendrocalamus hamiltonii*, with huge culms spreading from a common base in all directions, making walking very difficult.

CONCLUSIONS.

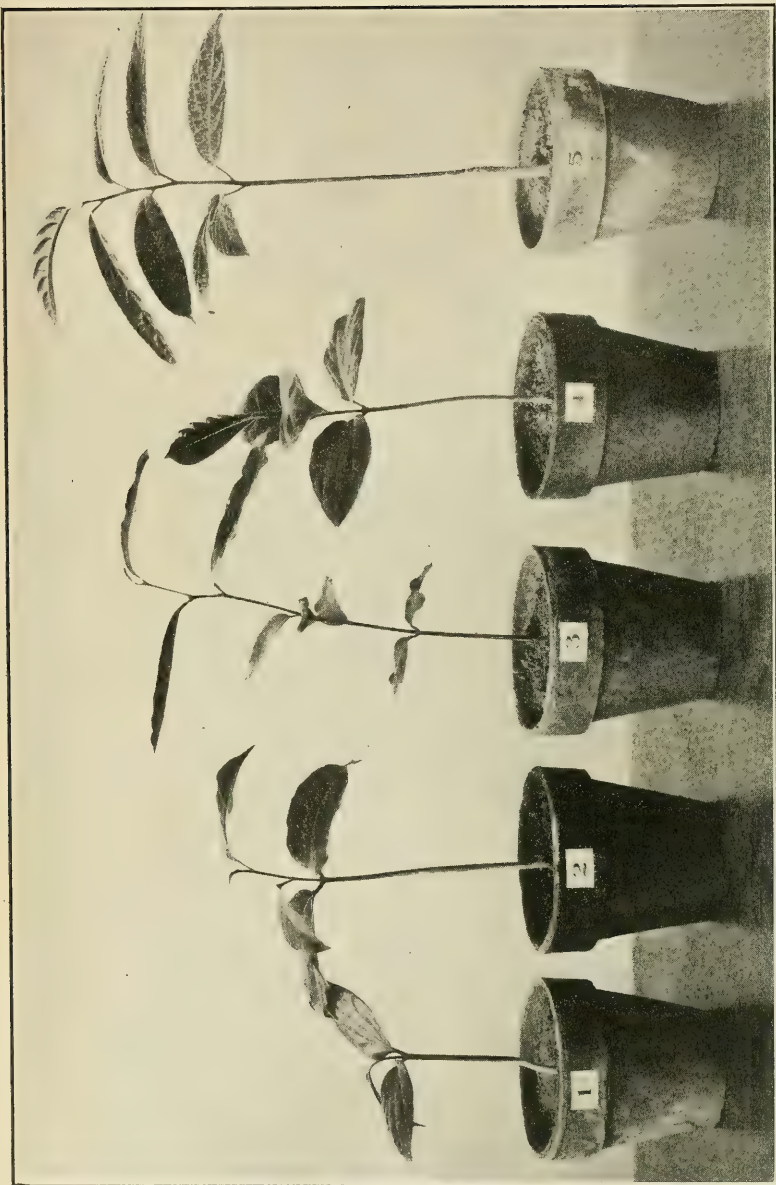
The facts brought to light in this recent survey show that the dealers in chaulmoogra oil (that derived from *Taraktogenos kurzii*) have never seen the tree in its wild state. Even the native Bengal dealers in Chittagong had not been in the forests of the Chittagong Hill tracts. All depend on jungle people for collecting the seeds, which are known by different native names in the various regions in which they grow. Smith, Stanistreet & Co., of Calcutta, claimed to have a tree growing in their compound, but on examination it was found not even to belong to the family Flacourtiaceæ, to which *Taraktogenos* belongs. The collecting of the seeds is, then, in the hands of jungle people, who are more or less indolent. Moreover, the conditions under which these seeds are collected are such, as has already been explained, that at least 50 per cent of the crop is lost every year. The Burmese name kalaw is applied to more than one species, and these species resemble each other so closely that the jungle people make no distinction between them (Pl. XV). Seeds of these trees are sent to markets and bazaars under the collective name of kalaw, where they are bought up by dealers who manufacture chaulmoogra oil from them.

Another point of interest and one of which very little is known is that *Taraktogenos kurzii* and kindred species do not bear a regular yearly crop but fruit sporadically and sometimes are without fruit for two years or more. The natives stated that fruit is collected by them every three years. The causes of the irregular fruit-



FRUITS OF THE TRUE AND FALSE CHAULMOOGRA TREES AND ALLIED SPECIES. (ABOUT ONE-FOURTH NATURAL SIZE.)

These fruits were collected in the forests of Burma, Siam, and Assam and constitute the first photographic record of the species which yield chaulmoogra and hydnocarpus oils and of *Gynocardia odorata*, which was long supposed to be the source of chaulmoogra oil. 1, *Turkogenos* sp. (?), supposedly *T. kurzii*, from the Thungayinon forests, Kawkerik Hills, Lower Burma, a 2-day journey from Myawadi, Burmese-Siamese boundary; 2, *Hydnocarpus wightiana*, from tree cultivated in Sibpur Botanic Gardens, Calcutta, India; 3, *Turkogenos kurzii*, from near Kyokta, Upper Chindwin district, Northwest Burma; 4, seeds of *Turkogenos kurzii*, shelled and unshelled; 5, *Hydnocarpus anhelminthica*, from Bangkok, Siam; 6, *Hydnocarpus castanea*, from near Oklada, Martaban Hills, Lower Burma; 7, *Gynocardia odorata* (false chaulmoogra), from the Berjan forests, Lakhimpur district, Assam. (Photographed by E. L. Crandall, Washington, D. C., August, 1921; P27012FS.)



SEEDLINGS OF THE TRUE AND FALSE CHAULMOOGRA TREES AND ALLIED SPECIES.

From seeds collected in 1920 in Siam and Burma.

None of the true chaulmoogra trees from Burma have ever been in cultivation before. Seedlings like the above are now growing in the Botanic Gardens of Kew and Singapore and in the Government Nurseries of Honolulu; also at the Leper Settlement of Dr. McKean, of Chingnam, Siam (and those of *Taraktogenos kurzii* in the Hongkong Botanic Gardens), fresh seeds having been sent by the writer of this bulletin direct from the forests to these institutions. The seedlings here shown are growing in the greenhouses of the Department of Agriculture at Washington, D. C. 1, *Taraktogenos kurzii*; 2, *Hydnocarpus castanæa*; 3, *Hydnocarpus anthelmintica*; 4, *Hydnocarpus wightiana*; 5, *Gynocardia odorata*. (Photographed by E. L. Crandall, Washington, D. C., August, 1921; P2704FS.)

ing habit of chaulmoogra trees are not known, but the fact that the trees are polygamous may have something to do with this. The flowers are undoubtedly dependent on insects for pollination, and while it is said of the species of *Hydnocarpus* that male flowers with rudimentary ovaries and female flowers with regular stamens but without pollen occur at the same time with strictly male and female flowers, it must be stated that on the trees of *Hydnocarpus anthelmintica* (in Bangkok) and of *H. curtisii* (in Penang) examined by the writer, only male flowers were found, and in the first species male flowers with a well-developed hirsute style. It may also be that this group of trees does not flower every year and that they are ali biennial fruiters. It is well worth while to study these questions, as very little is known of the flowering habits of these trees; in fact, the female flowers of *Taraktogenos kurzii* have never been found.

The remoteness from civilized centers of the forests where these trees occur, the danger and difficulty encountered in collecting the seeds (which may not be found every year), and also the conditions under which seeds are at present collected would point to the necessity of starting plantations of *Taraktogenos kurzii*, which is known to yield the true chaulmoogra oil, and also of such species of *Taraktogenos*, *Hydnocarpus*, and *Asteriastigma* as yield oils of similar composition. This would assure a steady supply and a uniform crop and avoid the possibility of having several species confused, as undoubtedly is the case at present in certain localities. It has been stated by an eminent authority that owing to the very encouraging work carried on in Hawaii and the great success achieved in the treatment of leprosy with chaulmoogra-oil derivatives, the lowest yearly demand will be for 1,000,000 liters of oil. The present output, the conditions under which the seeds are collected, and the uncertain fruiting periods of these species make it certain that the demand will far exceed the output. With this in view, the expedition was undertaken by the writer, of whose work this is a preliminary report, for the purpose of securing viable seeds of as many species as possible, and these seeds are now growing in several places. (Pl. XVI.)

The following suggestions are offered regarding the requirements for establishing plantations of *Taraktogenos kurzii*. The soil should be of a sandy nature, preferably quartz sand. Perfect drainage is necessary, and undulating or hilly land is preferable. The region should have a distinct rainy season with a pronounced dry season in the winter months, but still with considerable humidity. The winter temperature should not fall below 40° F. The foregoing represent approximately the climatic and soil conditions of this species in its native habitat. Other species, such as *Hydno-*

carpus anthelmīthica, require slightly different conditions; but all species of *Hydnocarpus* and *Taraktogenos* require well-drained sandy or loamy silt soils and grow best along creek beds or on the banks of streams. All require climates necessary for an evergreen rain forest, such as is found in Burma and elsewhere in India.

RECOMMENDATIONS.

Owing to the insufficient knowledge we possess regarding the species of both *Hydnocarpus* and *Taraktogenos*, and even of such an important species as *Taraktogenos kurzii*, the writer would recommend that a thorough survey be made of all the known species. All the given localities, as far as possible, should be visited and complete material collected. Seeds should be secured in quantities, both for germination and for chemical examination. Photographs should be taken of each species in its native haunt and fresh specimens should be photographed. Soil samples should be taken for chemical analysis and all such data should be gathered as plant associations, native names, medicinal uses, etc. The whole group of *Pangieæ*, especially the species of *Taraktogenos*, *Hydnocarpus*, and *Asteriastigma*, should be thoroughly monographed. Complete fruits as well as flowering material should be preserved in formalin, and wood samples should also be taken.

During the writer's stay in Calcutta, he worked on this group of plants in the Sibpur Botanic Garden Herbarium, the repository of King's types, and found among the material (which is at best fragmentary) possibly fifteen undescribed species of either *Hydnocarpus* or *Taraktogenos*. Complete notes were taken as well as photographs of the described and undescribed species; in nearly every instance detailed information is given as to localities, so that it will be very easy to locate these species. A survey of this group would be of great humanitarian interest, as among the many species of *Hydnocarpus* and *Taraktogenos* some may be found of more value from a pharmaceutical standpoint than *Taraktogenos kurzii*. *Asteriastigma macrocarpa* especially should be investigated. If plantations are to be established it is of the utmost value to know which of the numerous species should be planted. The best yielder of fruits, the largest fruited, and those yielding the proper oil in largest quantity should be selected. Special attention should also be given to climatic and soil conditions and environment.

The chemical part of this work would be of the greatest interest, for as yet complete investigations have been made only of the oils from *Taraktogenos kurzii*, *Hydnocarpus wightiana*, *H. anthelmīthica*, and the so-called false chaulmoogra (*Gynocardia odorata*). Less

complete examinations have been recorded of the oils from *Hydnocarpus venenata*, *H. alcalae*, and *H. alpina*.

The botanical discussion of the subject, together with the results of a chemical examination of the material, could then be issued in the form of a monograph on the tribe Panigieæ, family Flacourtiaceæ.

It is the writer's urgent recommendation that such a survey be undertaken.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1058

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

March 6, 1922

STERILITY OF OATS.¹

By CHARLOTTE ELLIOTT, *Scientific Assistant, Laboratory of Plant Pathology.*

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INTRODUCTION.

At the time when oats are maturing in the field, panicles having a part of the spikelets undeveloped or sterile are often sufficiently abundant to attract attention and to cause some concern because of the resulting reduction in yield. This sterility was first observed by the writer in connection with the halo blight of oats. In fields showing considerable halo blight there are usually some plants with the flag leaf and sheath badly spotted and yellowed. As the panicles emerge from these yellowed sheaths, often as many as half of the spikelets will be found to be sterile. This sterility usually occurs at the base of the panicle, but occasionally part of the upper spikelets are undeveloped. The fact that panicles emerging from yellowed sheaths usually show more sterility than panicles from unspotted sheaths might lead to the conclusion that the sterility is due to the bacterial disease. Thomas F. Manns, in his bulletin on the bacterial blight of oats (1909),² describes and figures (pl. 14, p. 161) this condition and states that "blast" (sterility) of oats is more or less directly proportional to the extent of blade blight. He says that in some cases the blast may be due directly to the killing of parts of the panicles by contact with blight lesions, but as a rule it is caused by the reduced vitality of the plant occasioned by the blade blight several weeks before the panicle emerges.

¹ These experiments were begun at the suggestion of Prof. L. R. Jones, of Madison, Wis.

² Manns, Thomas F. The blade blight of oats—a bacterial disease. Ohio Agr. Exp. Sta. Bul. 210, p. 161, pl. 14. 1909.

The extreme and average percentages of sterility are shown in boldface figures. Abbreviations (in reading columns): Minn. = Minnesota; Orga. = inoculum of halo-blight organism; Ped. = pedigree; Wis. = Wisconsin.]

Variety and bundle conditions.		* Normal and sterile spikelets counted.																																										
		Panicle 1.		Panicle 2.		Panicle 3.		Panicle 4.		Panicle 5.		Panicle 6.		Panicle 7.		Panicle 8.		Panicle 9.		Panicle 10.		Average.																						
Sprayed with—	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.	Total.	Sterile.																						
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.																						
Wis. Ped. 1 (Wisconsin Wonder):	57	44	13	22	102	86	16	15	76	71	5	6	37	29	8	1	58	41	17	29	36	32	4	11	33	27	6	18	53	44	9	16												
	33	25	8	24	42	22	20	47	28	18	10	35	29	12	30	36	23	13	38	35	48	17	26	32	22	10	31	25	23	2	8	25	14	11	44	15	3	16	34	27	10	29		
	25	19	6	24	54	30	55	57	43	14	27	57	14	19	23	17	6	26	30	32	18	38	46	28	1	24	37	11	34	37	21	16	43	40	26	14	33	48	14	32				
	66	58	8	12	56	40	16	28	58	42	16	7	13	61	43	18	29	15	38	7	15	89	70	16	18	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3				
	47	33	14	29	55	34	21	38	30	25	5	16	56	38	13	32	24	23	11	32	48	38	10	20	46	32	14	30	58	47	11	18	53	28	23	47	17	33	14	23				
	43	40	3	6	33	30	3	9	33	30	3	9	49	38	11	22	24	29	5	14	45	41	4	8	44	39	5	11	40	38	2	5	40	38	2	5	40	35	4	10				
	19	17	2	10	26	23	1	3	20	17	3	15	21	19	2	9	15	14	1	6	15	15	0	0	22	18	0	0	22	18	0	0	22	18	0	0	22	18	0	0				
	19	17	2	10	26	23	1	3	20	17	3	15	21	19	2	9	15	14	1	6	15	15	0	0	22	18	0	0	22	18	0	0	22	18	0	0	22	18	0	0				
	36	33	3	8	28	22	4	13	35	30	5	14	49	46	3	6	43	40	3	6	43	40	3	6	43	40	3	6	43	40	3	6	43	40	3	6	43	40	3	6				
	26	23	3	11	19	17	2	10	28	27	1	3	32	29	3	9	30	25	5	16	15	15	0	0	22	18	0	0	22	18	0	0	22	18	0	0	22	18	0	0				
Wis. No. 4 (Swedish Select):	29	27	2	6	41	38	3	7	31	27	4	12	40	33	7	17	50	47	3	6	14	29	5	14	32	32	0	0	36	33	3	8	48	38	10	20	32	28	4	12	37	33	4	10
	45	41	5	11	45	36	9	20	48	44	4	8	49	37	12	24	41	28	13	31	38	30	8	21	31	26	5	16	16	44	12	21	33	24	9	27	28	23	5	17	41	33	8	19
	40	35	12	15	12	15	12	20	18	16	2	11	28	28	0	0	23	23	0	0	30	25	5	16	23	1	5	16	23	1	5	16	23	1	5	16	23	1	5	16	23	1	5	
	32	24	8	25	46	36	10	21	48	36	10	21	48	36	10	21	48	36	10	21	48	36	10	21	48	36	10	21	48	36	10	21	48	36	10	21	48	36	10	21	48	36	10	21
	36	31	15	22	47	42	5	10	51	44	7	13	47	38	9	19	53	45	8	18	55	47	5	10	51	44	7	13	47	38	9	19	53	45	8	18	55	47	5	10	51	44	7	13
Wis. Ped. 5 (Swedish Select):	30	30	20	40	58	34	24	41	42	30	12	28	30	12	28	30	12	28	30	12	28	30	12	28	30	12	28	30	12	28	30	12	28	30	12	28	30	12	28	30	12	28		
	20	19	1	5	22	22	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0
	30	26	4	13	21	20	1	4	32	32	0	0	29	29	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0
	21	19	2	9	37	35	2	5	43	42	1	2	30	30	0	0	35	33	2	5	22	22	0	0	42	41	1	2	38	37	1	2	25	24	1	2	25	24	1	2	25	24	1	2
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	
Wis. Ped. 7 (Kherson):	20	19	1	5	22	22	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0	47	47	0	0
	30	26	4	13	21	20	1	4	32	32	0	0	29	29	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0	28	28	0	0
	21	19	2	9	37	35	2	5	43	42	1	2	30	30	0	0	35	33	2	5	22	22	0	0	42	41	1	2	38	37	1	2	25	24	1	2	25	24	1	2	25	24	1	2
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	
	37	37	0	46	41	5	10	40	37	3	7	52	49	3	5	48	46	2	4	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	44	42	0	0	

Wis. Ped. 13 (Garton No. 466):

Bundle 1, untreated.....	72.57	15	20	46.37	9	19.40	50	10	14	17.41	6	12	44.37	7	1571.58	13	18.70	63	7	10.00	51	9	15.31	28	3	9.27	24	3	11.52	44	8	15					
Bundle 2, untreated.....	37.28	8	21	52.29	23	44.31	24	7	22	20.14	6	30	61.28	23	45.43	34	9	20.33	18	15	45.29	6	17	47.25	22	46	55.31	24	43	40	26	14	35				
Bundle 3, injured.....	32.19	13	40	35.19	16	43.29	12	17	37	33.20	13	39	37.19	18	48.16	5	8	35.41	30	65	56.26	9	25	40.20	4	8	71.43	28	39	51.42	9	17	39.44	15	25		
Bundle 4, injured.....	33.30	3	9	77.46	37	48.60	27	31	30.48	12	20	52.43	9	17	36.51	5	8	35.41	24	36	45.41	4	24	36.45	41	20	7	22	50.17	33	66	32.18	14	43	41.22	19	46
Bundle 5, injured.....	31.14	3	9	77.46	37	48.60	27	31	30.48	12	20	52.43	9	17	36.51	5	8	35.41	24	36	45.41	4	24	36.45	41	20	7	22	50.17	33	66	32.18	14	43	41.22	19	46
Bundle 6, in sheaths, uninjured.....	43.48	5	11	76.68	19	73.51	21	30	58	19.22	27	55	49.39	10	20	68.38	30	42	84.20	11	35	51.24	7	17	52.50	8	12	61.54	7	11	54.46	7	11	54.46	7	11	
Bundle 7, in sheaths, uninjured.....	62.30	12	19	63.50	13	20.54	40	14	27	37.49	8	14	40.32	8	20	49.37	12	24	42.31	11	26	50.42	8	16	52.40	12	23	61.42	19	31	53.41	11	20	53.41	11	20	
Wis. Ped. 14 (Garton No. 585):																																					
Bundle 1, untreated.....	46.38	8	17	36.34	2	54.13	38	3	7	26.25	1	3	67.65	2	24.13	29	2	45.43	11	20	38.37	1	23	1.28	3	9	9.32	30	2	64.17	3	7	3	7	3		
Bundle 2, untreated.....	21.20	1	4	45.36	9	20.28	26	2	7	17.34	13	27	22.19	3	13	52.32	30	38	66.41	25	37	37.29	8	21	44.35	9	20	26.24	2	7	38.27	3	23	3	23		
Bundle 3, bloom off.....	24.23	1	4	34.33	1	24.32	29	14	32	24.23	1	4	25.20	5	20	50.38	12	24	27.21	6	22	32.28	4	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
Bundle 4, cut scalped.....	37.31	6	16	43.42	1	24.42	40	2	4	21.20	1	4	39.38	1	20	30.28	2	6	20.19	1	5	42.41	1	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
Bundle 5, cut scalped.....	21.21	0	0	35.30	5	14.47	29	18	38	47.29	18	38	58.32	6	15	60.47	13	21	36.27	9	25	48.34	14	26	54.51	3	54	52.32	10	23	42.33	9	21	1	1		
Bundle 6, in sheaths.....	38.35	3	7	53.44	9	16.34	29	5	14	29.26	3	10	84.29	5	14	43.38	5	11	21.19	2	9	38.33	5	13	44.39	5	11	30.28	2	6	36.32	4	11	1	1		
Wis. Ped. 15 (Garton No. 453):																																					
Bundle 1, untreated.....	34.34	0	0	52.52	0	0	42.42	0	0	50.50	0	0	84.34	0	0	38.55	0	0	48.47	1	2	46.45	1	2	26.26	0	0	24.24	0	0	41.41	0	2	0	0		
Bundle 2, injured.....	54.53	1	1	49.48	1	2	40.40	0	0	36.63	3	44	37.7	7	13	37.28	7	18	36.31	5	13	53.45	8	15	39.37	2	5	49.48	1	2	46.43	3	5	7	7		
Bundle 3, cut.....	23.23	0	0	25.22	3	12	24.21	3	12	33.31	2	6	27.22	5	18	41.40	1	2	35.34	1	2	58.51	7	12	44.37	7	15	18.18	0	0	32.29	2	6	0	0		
Bundle 4, bloom off.....	37.35	2	5	40.36	4	10	40.38	2	5	28.26	2	7	44.38	6	13	45.43	2	4	67.48	49	60	72.68	4	5	39.33	6	15	67.58	9	13	50.42	8	16	0	0		
Bundle 5, cut.....	38.29	9	23	30.26	4	13	40.35	5	12	32.31	1	3	46.40	6	13	42.34	8	19	34.30	4	11	38.33	5	13	50.40	10	20	53.50	3	5	40.34	5	12	0	0		
Wis. No. 22 (Improved Ligowo (Minn. No. 6):																																					
Bundle 1, untreated.....	52.48	4	7	57.51	6	10	55.51	4	7	85.75	10	11	52.46	6	11	40.72	8	10	54.48	6	11	82.77	5	6	72.70	3	4	69.50	10	14	65.59	6	9	0	0		
Bundle 2, untreated.....	84.77	7	8	75.64	11	14	51.55	6	11	41.79	2	4	39.56	13	15	43.35	8	18	41.39	5	11	82.77	5	6	72.70	3	4	69.50	10	14	65.59	6	9	0	0		
Bundle 3.....	48.33	15	3	62.37	25	4	73.41	32	43	34.54	46	47	35.29	36	59	34	25	42.55	40	25	82.72	34	38	52.74	44	29	38.53	27	6	13	64.37	27	42	0	0		
Bundle 4.....	41.26	15	3	62.37	25	4	73.41	32	43	34.54	46	47	35.29	36	59	34	25	42.55	40	25	82.72	34	38	52.74	44	29	38.53	27	6	13	64.37	27	42	0	0		
Bundle 5, uninjured.....	42.37	5	11	38.24	10	34.75	32	31	43	59.33	26	44	34.21	32	57	38	49	56.12	20	22	82.89	57	52	56.61	38	23	37.73	40	33	45.63	34	28	44	0	0		
Wis. No. 25 (Silvermine):																																					
Bundle 1, untreated.....	71.54	17	23	50.39	11	22	53.42	11	20	84.80	4	4	70.60	10	14	31.46	15	24	44.37	7	15	88.73	15	17	63.54	9	14	76.61	15	19	66.54	11	16	0	0		
Bundle 2, untreated.....	48.44	4	8	60.50	10	16	59.46	13	22	73.62	11	15	55.71	14	16	37.52	5	8	73.58	15	20	56.53	3	5	55.49	3	5	55.49	3	5	55.49	3	5	55.49	3	5	
Bundle 3.....	39.23	16	41	40.38	2	5	54.26	28	51	42.21	21	50	35.31	34	52	37.27	25	40	47.17	37	34	49.87	68	19	21	49.22	27	59	45.34	15	30	55.33	22	40	0	0	
Bundle 4, uninjured.....	75.58	37	49	75.33	32	42	70.33	38	54	70.30	40	57	60.29	31	51	39.30	29	49	89.34	35	50	47.20	27	57	68.30	30	47	.....	.....	.....	.....	.....	.....	.....	.....		
Bundle 5, bloom off.....	64.26	38	59	80.37	43	57	80.30	46	60	82.36	46	66	55.12	43	78	30.32	58	72	50.14	36	72	52.11	21	65	55.15	40	72	60.22	38	63	63.23	40	63	0	0		
Bundle 6, in sheaths.....	56.50	6	10	37.30	7	18	48.43	5	10	37.30	7	18	48.43	5	10	37.30	7	18	48.43	5	10	37.30	7	18	48.43	5	10	37.30	7	18	48.43	5	10	37.30	7	18	
Bundle 7, in sheaths.....	25.24	1	4	56.42	14	25	58.45	13	22	83.65	28	30	72.43	29	40	47.35	12	25	67.55	12	17	83.68	15	18	73.56	17	23	57.39	18	31	63.47	15	23	0	0		
Wis. No. 49 (Kherston):																																					
Bundle 1, untreated.....	66.53	13	19	63.54	9	14	68.58	10	14	56.48	8	14	86.54	12	18	11.57	4	6	50.47	3	6	67.58	9	13	71.53	18	25	57.50	7	12	62.63	9	14	0	0		
Bundle 2.....	34.22	12	35	66.44	22	33	52.26	26	56	72.49	23	31	62.50	12	19	14.25	17	43	41.38	33	46	50.20	27	54	59.20	9	31	83.35	48	57	56.33	23	41	0	0		
Bundle 3.....	26.14	12	46	51.21	30	58	62.26	36	55	49.27	22	44	62.30	32	51	17.20	19	47	45.24	16	8	33.71	27	44	61	72.29	43	59	68.57	11	16	52.26	25	43	0	0	

It is quite evident, however, that considerable sterility occurs on oat panicles which have not come in contact with diseased leaves or sheaths, and even in fields where there has been little or no bacterial blight; also there is evidence that in years of severe bacterial blight early in the season the yield per acre has not been reduced, but sometimes has been greater than when there was less blight.

In order to learn more about the relationship of the halo blight to the sterility of oats the observations and experiments described in the following pages were made.

EXPERIMENTS OF 1918.

During the season of 1918, 11 varieties of oats were used for inoculation experiments. In each variety bundles containing about a dozen plants were sprayed with water suspensions of the halo-blight organism and covered with glassine bags for two or three days. One bundle was sprayed without being injured in any way and another after the plants had been drawn between the fingers to rub off the bloom. The plants of a third bundle of each variety were injured by needle pricks or were cut with a scalpel before spraying. Check bundles of each variety, injured and uninjured, were sprayed with sterile water and also covered with bags. In some cases water suspensions of the organism were sprayed into unopened sheaths and sterile water into similar plants as checks. (Pls. I to IV.)

In most of the varieties the sheaths were about ready to open or were already partly open. In Wisconsin Pedigree 7 the heads were entirely out of the sheaths and were inoculated to learn whether or not the spikelets themselves were susceptible to infection with the halo-blight organism and what the effect of infection would be. In the oat panicle the uppermost spikelets develop first and at the time when the sheath is about ready to open are usually fully grown, while those at the base are still only partly developed. The difference in the stage of development of the spikelets on the panicle influences, of course, the results of the experiments where inoculations are made upon panicles about to emerge from the sheath. The almost fully developed spikelets at the top are less influenced by the inoculum than the partly developed ones at the base.

When these inoculated and check plants were mature and were collected for recording the results, a bundle of untreated plants of each variety was also collected in order to compare the proportion of sterility with that of treated plants. The results of this set of inoculations, together with the amount of sterility found on untreated plants, are shown in Table I, and a brief summary of the same is presented in Table II.



WISCONSIN NO. 22 OATS. IMPROVED LIGOWO (MINNESOTA NO. 6),
UNTREATED.

Collected in July, 1913, at Madison, Wis. Photographed in January, 1921. Three-fourths
natural size.



WISCONSIN NO. 22 OATS, SPRAYED WITH STERILE WATER ON JUNE 29, 1918.

Collected in July, 1918. Photographed in January, 1921. Three-fourths natural size.



WISCONSIN NO. 22 OATS, SPRAYED WITH WATER SUSPENSION OF "STOCK"
HALO ORGANISM.

Not injured before spraying on June 29, 1918. Collected in July, 1918. Photographed in
January, 1921. Three-fourths natural size.



WISCONSIN NO. 22 OATS, SPRAYED ON JUNE 29, 1918, WITH WATER SUSPENSION OF "STOCK" HALO ORGANISM AFTER INJURY BY NEEDLE PRICKS.

Collected in July, 1918. Photographed in January, 1921. Three-fourths natural size.

TABLE II.—Average percentages of sterility in 11 varieties of oats, as shown by inoculation experiments in 1918.

Variety.	Untreated, uninjured.	Sprayed with water.		Sprayed with organism.	
		Uninjured.	Injured.	Uninjured.	Injured.
Wisconsin Pedigree 1.....	16	29		32	
Wisconsin Pedigree 3.....	10	9		12	
Wisconsin No. 4.....	7	10		7	
Wisconsin Pedigree 5.....	8	27		19	
		29		16	29
Wisconsin Pedigree 7.....	1	3		4	6
		3			
Wisconsin Pedigree 13.....	15	35	47	25	46
Wisconsin Pedigree 14.....	7	23	5		21
			15		
Wisconsin Pedigree 15.....	0.4		6		16
			7		12
Wisconsin No. 22.....	14	42		40	
		44			
Wisconsin No. 25.....	16	40		50	63
	14				
Wisconsin No. 49.....	14	41			
		48			

On normal untreated plants of the 11 varieties tested the amount of sterility varied from a fraction of 1 per cent to as much as 16 per cent. Sprayed with water suspensions of bacteria and with sterile water and treated as previously described, the proportion increased from 2 to 47 per cent. In some cases there was more sterility on plants sprayed with bacterial suspensions than on plants of the same variety sprayed with sterile water. In other varieties the reverse was true. On the whole, the amounts of sterility produced by either method seem to be about equal. If this is so, the bacteria are not the cause of the sterility in the varieties included in these experiments.

Wisconsin Pedigree 7 oats were sprayed when the panicles were entirely out and the spikelets practically full size. Although every spikelet was yellowed with halo lesions, the spikelets continued to fill out, as in untreated panicles.

In a plat of Wisconsin Pedigree 14 oats which was untreated a few panicles appeared which showed halo lesions on from a few to all of the spikelets in a panicle, but in spite of these lesions the spikelets were apparently as well developed as those unspotted.

EXPERIMENTS OF 1920.

During the season of 1920 panicles of oats were collected at random in oat fields and counts made of sterility; also another set of experiments was carried on to learn more of the possible relation of bacteria to sterility in oats. Bacterial suspensions and sterile water were sprayed into the unopened sheaths of plants about two-thirds grown. These were covered with glassine bags for three days, as in previous experiments. The results of these tests are shown in Tables III and IV.

TABLE III.—*Counts of sterility observed in oat panicles collected at random in a field of Wisconsin Pedigree 1 (Wisconsin Wonder), at Madison, Wis., July 21, 1920.*

[The extreme and average percentages of sterility are shown in boldface figures.]

Panicle.	Normal and sterile spikelets counted.											
	Bundle 1.				Bundle 2.				Bundle 3.			
	Total.	Normal.	Sterile.		Total.	Normal.	Sterile.		Total.	Normal.	Sterile.	
			Number.	Per cent.			Number.	Per cent.			Number.	Per cent.
No. 1.....	45	42	3	6	40	34	6	15	67	52	15	22
No. 2.....	53	45	8	15	50	45	5	10	51	41	10	19
No. 3.....	38	27	11	28	43	38	5	11	82	58	24	29
No. 4.....	44	42	2	4	32	28	4	12	61	45	16	27
No. 5.....	40	32	8	20	65	41	24	37	85	60	25	29
No. 6.....	40	39	1	2	37	33	4	10	72	54	18	25
No. 7.....	42	38	4	9	31	29	2	6	75	49	26	34
No. 8.....	41	37	4	9	38	34	4	10	93	66	27	29
No. 9.....	34	25	9	26	55	41	14	25	62	52	10	16
No. 10.....	38	32	6	15	41	35	6	14	62	46	16	25
No. 11.....	42	39	3	7	54	37	17	31	77	62	15	19
No. 12.....	60	48	12	20	54	37	17	31	73	40	33	45
No. 13.....					50	35	15	30	81	52	29	35
No. 14.....									69	45	24	34
No. 15.....									90	67	23	25
No. 16.....									76	53	23	30
No. 17.....									78	55	23	29
No. 18.....									65	50	15	23
No. 19.....									51	35	16	31
No. 20.....									78	59	19	24
No. 21.....									72	54	18	25
No. 22.....									45	34	11	24
No. 23.....									48	37	11	23
No. 24.....									43	29	14	33
No. 25.....									49	40	9	18
No. 26.....									47	35	12	25
No. 27.....									53	40	13	24
No. 28.....									72	56	16	25
Average.....	43	37	5	13	45	35	9	18	67	48	18	26

The panicles recorded in Table III were collected on July 21 without regard to sterility from an acre plat on the agricultural grounds of the University of Wisconsin. It was noticeable that every panicle showed some sterility, the amount varying from 1 spikelet per panicle in bundle 1 to 33 spikelets per panicle in bundle 3. This field from which the panicles were taken was practically free from halo blight. There were no lesions on the upper leaves, flag leaves, or panicles, and only an occasional lesion on a lower leaf could be found. In the case of this variety there seems to have been no connection whatever between the halo blight and the sterility recorded above, yet in bundles 2 and 3 the average sterility was more than a third of the whole number of spikelets.

In the 1920 experiments (Table IV), as in 1918, water and bacterial suspensions sprayed into oat sheaths produced more sterility than occurred naturally. The average of 21 per cent of sterility on untreated plants is high, but this increased to 40 and 52 per cent when water was sprayed into the sheaths and to 44 and 63 per cent with bacterial suspensions. In this experiment the bacterial sus-

pension retarded growth more than the sterile water. In a number of cases the panicles did not push out of the sheaths, remaining undeveloped inside, and were so moldy that it was practically impossible to make counts. How much the mold had to do in retarding development could not be determined. Counts from these panicles are given where possible.

TABLE IV.—*Relation of halo blight and stripe organisms to sterility in oats, as shown by inoculation experiments with Wisconsin Pedigree 5 (Swedish Select) at Madison, Wis., June 25, 1920.*

[The extreme and average percentages of sterility are shown in boldface figures.]

Panicles.	Normal and sterile spikelets in treated and untreated panicles. Inoculum in sheaths.																			
	Untreated, bundle 1.				Sterile water.								Halo-blight organism.							
					Bundle 2.				Bundle 3.				Bundle 4.				Bundle 5.			
					Sterile.				Sterile.				Sterile.				Sterile.			
	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.
No. 1.....	52	38	14	26	22	12	10	45	31	18	13	41	17	10	7	41	...	10	...	...
No. 2.....	64	51	13	20	30	18	12	40	34	13	21	61	16	10	6	37	27	18	9	31
No. 3.....	58	46	12	20	37	23	14	37	20	9	11	55	...	0	...	100	12	11	1	8
No. 4.....	47	26	21	44	25	13	12	48	20	10	10	50	...	...	50	21	14	7	33	...
No. 5.....	53	44	9	16	33	18	15	45	20	8	12	60	20	9	11	55	28	13	15	53
No. 6.....	50	38	12	21	21	15	6	27	11	3	8	72	28	16	12	42	19	11	8	42
No. 7.....	36	24	12	33	39	25	14	35	30	16	14	46	...	0	...	100	...	0	...	100
No. 8.....	25	21	4	16	25	11	14	56	22	13	9	40	...	0	...	100	21	13	8	38
No. 9.....	43	41	2	4	23	12	11	47	28	11	17	60	22	10	12	54	21	10	11	52
No. 10.....	44	32	12	27	24	13	11	45	19	7	12	63	19	9	10	52	32	17	15	46
No. 11.....	41	28	13	21	21	12	9	42	27	9	18	66	23	11	12	52	...	...	...	...
No. 12.....	58	51	7	12	23	16	7	30	21	8	13	61	...	0	...	100	...	...	...	...
No. 13.....	...	...	...	...	37	26	11	29	23	9	14	60	...	4	...	...	...	...	...	...
No. 14.....	...	...	...	...	28	19	9	32	28	16	12	42	...	8	...	...	...	...	...	...
No. 15.....	...	...	...	...	26	10	16	61	25	9	16	64	...	8	...	...	...	...	...	...
No. 16.....	...	...	...	...	19	15	5	21	15	7	8	53	...	8	...	...	...	...	...	...
No. 17.....	...	...	...	...	30	13	17	56	24	14	10	41	...	...	...	...	...	...	...	...
No. 18.....	...	...	...	...	...	...	...	...	29	16	13	44	...	...	...	...	...	...	...	...
No. 19.....	...	...	...	...	...	...	...	...	20	10	10	50	...	...	...	...	...	...	...	...
No. 20.....	...	...	...	...	...	...	...	...	24	10	14	58	...	...	...	...	...	...	...	...
No. 21.....	...	...	...	...	...	...	...	...	33	18	15	45	...	...	...	...	...	...	...	...
No. 22.....	...	...	...	...	...	...	...	...	33	17	16	48	...	...	...	...	...	...	...	...
No. 23.....	...	...	...	...	...	...	...	...	26	13	13	50	...	...	...	...	...	...	...	...
No. 24.....	...	...	...	...	...	...	...	...	22	14	8	36	...	...	...	...	...	...	...	...
No. 25.....	...	...	...	...	...	...	...	...	24	12	12	50	...	...	...	...	...	...	...	...
Average.....	47	36	10	21	27	15	11	40	24	11	12	52	...	...	65	...	...	44	...	63

GENERAL SUMMARY.

Considerable sterility occurs on oat panicles without any apparent connection with halo blight and in fields where there are no bacterial lesions. The amount seems to vary with different varieties of oats, some showing more sterility than others during the same season under similar conditions.

The amount of sterility does not appear to be in proportion to susceptibility to halo blight. Wisconsin Pedigree No. 14 oats is the most susceptible to halo blight of the 11 varieties tested, but does not

show the greatest amount of sterility. By spraying plants with sterile water or water suspensions of bacteria and covering them for two or three days, the amount of sterility can be greatly increased. Although abundant halo lesions result from spraying with bacterial suspensions, the consequent sterility is only slightly, if any, greater in amount than that induced by sterile water.

It seems probable that rains falling about the time the oat sheaths are ready to open may have the same effect as the sterile water used in the experiments recorded here and that most of the sterility observed in oat fields is not the result of the halo-blight organism but of too much moisture about developing panicles.

The striking variations in percentages of sterility in different panicles of the same bundle (Table I, Wis. Ped. 14, bundles 1 to 6) and the high percentages of sterility in all the panicles of a few bundles (Table I, Wis. No. 25, bundles 4 and 5, and Table I, Wis. No. 22, bundles 3 and 4, 1918; also Table IV, bundles 2, 3, and 4, 1920) would seem to point to the condition of the oat flowers at the time of rain or spraying as a controlling factor in the amount of sterility. If, however, the variations in the amounts of sterility in different varieties should prove constant from year to year the varieties found to be susceptible could be discarded and hardier ones grown. Records for several years from parallel plats of varieties which have shown different amounts of sterility in one season might give interesting and practical results.

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May 19, 1922

RESEARCH METHODS IN THE STUDY OF
FOREST ENVIRONMENT.By CARLOS G. BATES, *Silviculturist in Charge of Fremont Forest Experiment Station*, and RAPHAEL ZON, *Forest Economist*.

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INTRODUCTION.

OBJECT.

Forestry, like engineering or medicine, is largely an applied science. Its development is based on fundamental knowledge of the natural sciences. Knowledge of the tree itself is purely botanical

and physiological science. The first contact with its enemies and biotic aids leads into mycology and zoology. Investigation of the effect of environment upon the tree necessarily involves consideration of geology and soils, physics and chemistry, cinematology and solar radiation, as well as the biology of the tree's living companions. In measuring the volume and growth of tree and stands, as well as many of the conditions within and without the tree, there is need for mathematics somewhat beyond the elemental. And so on ad infinitum. The present-day forester is keenly alive to the need for help from every possible source of scientific information.

Unfortunately, the investigations undertaken by those trained in forestry must cover so wide a field, and are so often governed by some practical, economic, and immediate necessity, that there is no time or opportunity, and often a lack of the necessary training, for delving into the fundamental problems of the underlying sciences. It is therefore in keeping with the needs of forestry and the spirit of the times to call the attention of scientists in every line to the problems that confront foresters and to seek the cooperation of such scientists in solving them.

While the present bulletin is designed primarily for the aid of forest investigators—those who are giving all of their time to forestry—it is hoped that it will be suggestive to a great many others of problems well worthy of their serious study. An effort must be made to show to such workers the ways in which forestry is weak and as exactly as possible the nature of the problems with which foresters are confronted. To trained scientific workers the discussion of methods with which they are already more than familiar will seem unnecessary. To others familiar with the problems of forestry and perhaps almost overwhelmed by their magnitude it is hoped the same discussions may bring needed suggestions of a technical nature.

A method of investigation is to the scientist what a tool is to a mechanic. The point of view of the investigator, determined by his past experience, knowledge of facts, and philosophy, is to him what manual skill is to the mechanic. The investigator, like the mechanic, to be thoroughly effective, must be able on occasion to make new tools for new and special purposes.

Any suggestion of a handbook, presenting cut-and-dried methods by which research is to be conducted, would be repugnant to the true investigator. The aim of this bulletin must be to clarify the problems so that the investigator may readily choose for himself the method of approach, and not so much to recommend as to enumerate methods and equipment, describing their past accomplishments. If the following discussions do not hold strictly to this point, it should be

understood that it is the purpose of this bulletin to build a foundation for the future on the experience of the past, and to suggest the form of the superstructure rather than its architectural design. In this way it is hoped to save the actual designers much needless and fruitless effort.

SCOPE.

In surveying the present field of forest investigations and analyzing the factors which enter into the problems and the methods available for their solution, it appears that, although the number of problems is great and they may vary in character from region to region and from period to period, theoretically they may be conceived as falling into two essential groups. These two groups are (1) ecological and (2) statistical. In solving the ecological problems the aim is to express relations; in solving statistical problems the aim is to express the bare facts of forest growth.

This bulletin will be concerned wholly with ecological forest studies.¹ To some it may seem strange that the word "ecological" should be used rather than the more inclusive "biological." The choice is a question of aims and objectives. "Ecological" better expresses the objects of the knowledge foresters seek to gain. The practice of forestry is in a very large degree the application of ecology. As an example, a forester may be only slightly interested in the abstract physiological fact that trees require sunlight for their development. This fact is taken as a matter of course and allowed for. When, however, he finds that one of two species with which he is dealing requires much more sunlight than the other, or, in other words, does not react so readily to the stimulus of sunlight, the forester then finds a keen interest, because it is a practical interest, in this ecological factor and its relations.

Or, again, the matter may be expressed in this way: The forester, in dealing with a given species, feels that he is dealing with a biological entity whose characters he may know minutely or generally but which he can not change, except possibly through long-term

¹ The statistical group of problems, in distinction from the ecological, includes chiefly those which deal with the determination of the amount of standing timber, its increment, and other quantitative changes in the stand, with only general reference to the conditions governing, such as might be met in the use of arbitrary site quality classes. As a matter of fact, there can be no sharp line between ecological and statistical forest studies, and as forestry advances there will be a tendency to consider all growth in its ecological relations. It is, however, at the outset necessary to recognize certain standard methods for the measurement of growth, whatever their purpose or use. These methods are distinct from the processes which are ordinarily considered as essential to progress in ecology, and it is for this reason that "measurements," or statistical studies, are not included in the present discussion. The method of determining the growth, volume, and yield of forest stands is largely mechanical, though for sound progress it should, of course, involve knowledge of biology as well as mathematics. The caliper, hypsometer, scaling stick, log scale, increment borer, and tape are practically all the instruments that are required.

breeding. On the other hand, the environment of this entity can to a considerable degree be controlled, and its reactions to changes in environment can be observed. His concern is therefore not with the physiological functioning of the plant as such, but with its physiological functioning in relation to a given environment.

Control of environment is the cornerstone of the practice of forestry. The art of the forester is primarily the art of utilizing to best advantage the biological forces active in forest growth, through his ability to modify the environment. Any considerable use of forests means interference with the natural conditions and modification of some of the environmental factors, the sum total of which determined the character of the present forest. Forestry adapts this interference to produce the best results, from the standpoint of human needs. Therefore it has been thought best in this bulletin to take up each of the environmental factors separately, and to introduce only such a discussion of physiological facts as seems necessary to a proper conception of the methods of study of the environment.

Ecological forest studies deal with all problems which involve the determination of the effect of environmental conditions on reproduction, initiation, growth, and physiological functions. To this group belong such studies as the seed production of different species in different seasons and conditions; the characteristics of seeds as related to their origin; the correlation between the composition, succession, and growth of forest vegetation on the one hand, and the conditions of the environment on the other; the vast field of problems in natural reproduction and methods of cutting for definite silvicultural purposes; the various phases of forestation, including the germination of seed, requirements for shade and water of the different species, the planting of forest trees, and their competition for moisture and light with herbaceous and shrubby vegetation; and many similar problems. The methods and instruments available for the study of the ecological forest problems are essentially the same as those which are used in the study of the physiology and ecology of plants in general. They involve the measurements of such aerial conditions as precipitation, air temperature, the evaporating power of the air, wind velocity and wind direction, and sunshine intensity; and such subterranean conditions as temperature and moisture of the soil, its depth, structure, and chemical composition. The functioning of the tree in response to these conditions must also be measured by the means recognized and used by plant physiologists. The methods and instruments used in physiology, meteorology, and soil physics, therefore, are applicable in a large measure to the study of ecological forest problems, though often with modifications necessitated by the character of the plant and of its environment.

While it is true that in studying the present composition of a forest stand it is necessary, to a certain extent, to have the historical viewpoint in order to determine clearly how this stand was initiated and why it now supports one dominant species rather than another, still it must be recognized that historical studies and conjectures are outside the main domain of ecology. The purpose of ecology as an exact science must always be to measure present conditions and their reactions on the organism, reducing to precise terms relations between environment and life which may be already understood in general terms. In such processes no distinction will be made between a condition which is a direct result of the climate or site, one which is the result of cumulative effects of the presence of the plant formation, and one which may represent the current influence of the present plant formation. Thus, while recognizing in principle and in the application of results historical conditions and the so-called social relations which are particularly important in forest aggregations, it must be clearly understood that, in the current measurements with which this bulletin has to deal, the source of a given condition has no bearing on the method of its determination.

SAMPLE PLOT METHOD COMMON TO BOTH ECOLOGICAL AND STATISTICAL STUDIES.

A method common to both ecological and statistical problems is the method of sample plots. The details of the sample plot method vary with the purpose of the problem which is being investigated. The plot may vary in size from a square foot to an entire section. It may have all possible geometrical forms—circle, square, quadrangle, strip, or triangle. It may be used in the study of herbaceous vegetation, of seedlings in a nursery, or of virgin forests; for the purpose of studying the evolution of the vegetation, for bringing out the effect of a definite condition, for determining the growth of the vegetation, or for observing any other change that takes place in the plant association, whether it be grass, brush, or forest. The principle, however, remains everywhere the same; namely, the use of areas representative of a given type of vegetation for intensive observation over a long period of time.

NEED FOR A PERMANENT ORGANIZATION IN FOREST INVESTIGATIONS.

The great variety of forest stands, the difference between stands in different regions, and the longevity of trees make it difficult for an individual to complete any investigation on the life of the forest. This difficulty is now universally recognized. A permanent organization charged with such investigations has been formed in practically every country in which the care of the forests is a matter of national concern. This permanent organization consists of investigators assigned to forest experiment stations.

FOREST EXPERIMENT STATIONS.

Since it is practically impossible to follow all the changes which take place in a stand during its entire life of 100 years or more, the usual procedure is to carry on a number of observations simultaneously. By distributing the observations over stands of the same character, representing a large number of age gradations, the entire 100-year cycle of development of the stand may be encompassed in 20 years. Even then it often happens that a forest stand, because of an accident, such as fire or insect infestation, may become unsuitable for further observations. It is evident, therefore, that for reliable silvicultural conclusions it is necessary to have under observation a large number of forest stands for long periods of time, and, therefore, a permanent investigative organization, which will insure the completion of long-term experiments and correlate in a systematic and uniform way the observations conducted by many investigators throughout the country. The investigations which come as a general rule distinctly under the work of forest experiment stations are: (1) Forest meteorological observations; (2) distribution of species and types in relation to climate and soils; (3) studies of the growth, volume, and yield of forest stands; (4) studies of the effect of the source of seed upon the resulting forest stand; (5) experiments with the introduction of exotic species; (6) experiments with different silvicultural methods of cutting for the purpose of securing natural reproduction; (7) methods of artificial reproduction; (8) the study of the effect of different methods of thinning upon the growth of the main stand; and (9) studies of the effect of site upon the technical properties of the wood produced. These investigations are beyond the ability of an individual investigator to handle because their solution requires either a very long period of years, often exceeding the life of a single man, or the simultaneous establishment of many experiments in different places—a wholesale method of observations—or expensive apparatus. It is true that some of the problems involved have been studied by individual investigators with very suggestive results, but there is no doubt that forest experiment stations, being less subject to the uncertainties of individual effort, can conduct such studies with greater uniformity and assurance of success.

SHORT-TERM STUDIES.

Although in the study of forest stands the most reliable results will be secured only by permanent, well-equipped experiment stations organized and maintained by the Federal Government, States, or institutions, much can be accomplished also by comparatively short studies of individual investigators.

Studies which do not involve continuous observations for a long period of years or expensive stationary instruments and equipment—for example, microscopic and chemical studies of woods or studies of natural reproduction, distribution, and growth—may be conducted without permanent forest experiment stations; and even observations on climate in its relation to forest vegetation may sometimes be made on short field trips. Very often the painstaking observer, without extensive apparatus, will discover some fundamental facts which alter the conception of a given problem, and which therefore lead to far more productive efforts by the permanent organizations which can study the problem for longer periods. It is only by recognizing this principle of supplemental effort that substantial progress in forest investigations can be made. There should be no attempt to delimit the work of any organization or individual.

THE SIMPLE PHYSICO-PHYSIOLOGICAL CONCEPT.

Many ecological problems are less confusing to the beginner and are more likely to be approached by sound methods if, at the outset, a rather definite physical interpretation of life is accepted, for through such a concept is gained an idea as to the probable physical reaction to the environment and the method of measuring the physical conditions.

Thus, to begin with, the living mass of plants (the protoplasmic mass, primarily) may be conceived to be simply a colloidal mass of organic compounds with a peculiar affinity for water. Water is of fundamental importance to its life qualities. To supply the demand for water, the protoplasmic mass must possess a greater affinity for it than the soil or solution from which the water is to be obtained. The struggle for water is, primarily,¹ a contest between the colloids of the plant and the organic and inorganic (clay) colloids of the soil.

Secondly, it is inevitable that any object possessing water should lose the same by evaporation to the atmosphere until a balance is reached between the vapor pressure of the water-holding mass and that of the atmosphere. Such an equilibrium does not, necessarily, mean death, at least for certain kinds of tissues, but the small supply of water represented by equilibrium with ordinary atmospheric vapor is insufficient to permit photo-synthesis, metabolism, and transport within the plant. For continued functioning, the plant must be able to maintain its water supply above this level.

The objective of physiological functioning is reproduction, to which growth is only incidental. The object in the existence of any individual plant is to extract enough phosphorus¹ from the soil so that a peculiar accumulation of matter called a seed may be formed, with

¹ Phosphorus is mentioned only as an example of the vitally necessary elements obtained from the soil.

a sufficient affinity for water and a sufficiently close chemical combination to enable this embryonic plant to resist all of the forces of disintegration during a period of dormancy.

The first requirement, then, is that the present plant should live long enough to accumulate by absorption from the soil a quantity of phosphorus which may be concentrated in this one seed, or ten thousand seeds, as the case may be.

To accomplish this object, it is rather evident that a large amount of water must be absorbed and disposed of, with a resulting deposit of phosphorus and other solids as the water is evaporated. Even then there must be a strong tendency for such solids, if retained in solution, to diffuse back to the roots and into the soil. Not denying the possible ability of the plant to trap and hold phosphorus, or any other needed substance, at the point where needed, it seems necessary to call into play some other physical force to effect this concentration. The only other possible force is the electromagnetic affinity of energy for matter and of matter for energy. The ability of the plant to concentrate the essential inorganic substances in the best-lighted parts of its structure may thus be explained.

In other words, the requirement of plants for light is primarily a requirement for a concentration of essential substances needed for reproduction. But light can only be obtained where there is competition through growth. To insure the necessary amount of light, the individual plant is required to keep its head at least up to the level of the competitors, and the plant which becomes dominant is most certain to reproduce. Possible differences between plants, in their ability to make use of different kinds of light, need not be discussed here.

So, then, reproduction requires light, the need for light calls for growth, and growth in turn is possible only through the action of light in photo-synthesis, or the creation of new organic matter by the combination of water and carbon dioxide.

This necessary combination of water from the soil and carbon dioxide from the air can be effected only by exposing the cells containing water to the air, so that the carbon dioxide may be absorbed by these cells. The important feature ecologically is that such exposure inevitably results in considerable losses of water; and even though the cells so exposed may be somewhat protected, it is evident that carbon-dioxide absorption and water loss must, in a given plant, run about parallel, both being controlled by the size of the stomatal openings. The actual water loss, of course, will vary according to the dryness of the air, the concentration and vapor pressure of the contents of the exposed cell, and the intensity of the light in which the operation is performed. Thus a plant capable of making use of diffused light, or largely of the so-called actinic rays,

may function with less water loss than one exposed to the full heating effect of sunlight.

Until the distribution of essential substances, such as phosphorus, in the plant has been more fully and carefully studied in relation to light and the volume of the water stream, it is impossible to form a fair opinion as to whether the latter, and the transpiration of a large volume of water, are really essential to the end for which the plant exists. On this point botanists have ever been at variance. For the present, however, transpiration is believed to be merely an unavoidable concomitant of carbon-dioxide absorption, serving no useful purpose when carried to extremes, while always menacing the existence of the plant.

There is now only one more very essential point to be touched upon—a point which is of especial interest in connection with the study of trees because of their perennial character. The continuous absorption of water at the roots and its loss at the leaves of plants is necessarily accompanied by the absorption of all salts which are contained in the soil solution. There is undoubtedly some so-called selective absorption in the sense that any semipermeable membrane admits the complex molecules less readily than the simple ones, but the ability of the plant to differentiate between useful and unnecessary salts is not admitted. It is therefore inevitable that the leaves should accumulate quantities of material which can not be used; that there should be a tendency for such materials to diffuse back toward the roots; that when such material is present in sufficient quantities it should be precipitated or crystallized, and in such form should tend to obstruct the flow of water in the channels where it exists. It is conceivable, then, that all tissues which are actively engaged in the transport of water must eventually become “silted up” with this useless material and that this is the cause of senescence. Its best illustration is, perhaps, in the petiole of the broad leaf, through which narrow passage a large evaporating surface must be supplied. This conception explains quite well the eventual failure of leaves to function and their gradual drying and falling, even in those forms in which the leaves are not in the least sensitive to seasonal changes. It also, perhaps, explains the formation of heartwood in trees. The more important idea, however, is that it points to the necessity for growth to maintain existence. It is not sufficient that the “suppressed” tree (as every forester calls the tree growing with insufficient light) should obtain enough water to prevent the desiccation of the foliage. The plant must be periodically enabled to produce some new growth or it succumbs to senility, regardless of age. Apparently the maturity of a normal or even a dominant tree is attained soon after its limit of height is

reached, as it is then limited in its extensions for light and soon can not make the needed annual additions to its transporting system.

It is hoped that this discussion will clarify the point of view which prevails in the discussion of the individual environmental conditions.

MEASUREMENT OF ENVIRONMENTAL CONDITIONS AFFECTING FOREST VEGETATION.

The character of the forest and its very existence are determined by the climate, soil, and subsoil of the locality. The general character of the region, including the character of the vegetation and of the soil, is determined in the highest degree by the climate. The climate affects the region and vegetation in two ways: (1) It is at present the most important factor in the environment of the vegetation: (2) it has affected the present environment in its historical development: for instance, in the formation of the soils, their present physical and chemical composition being largely the result of the past climate in combination with other natural factors. The determination of the important features of a climate is not a simple matter. It must rest upon a sufficiently long series of observations at well-equipped meteorological stations.

CLIMATIC CHARACTERISTICS OF LOCALITY.

NATURAL CLIMATIC REGIONS.

The characteristics of a climate must be studied first of all by natural regions and the study based on the observations of several stations located in different parts of the same region. The climate of individual localities may best be analyzed by comparison with the climate of the entire natural region in which the locality is found or of a control station centrally located.

DATA OBTAINED BY WEATHER BUREAU.

For general climatic studies of the forest regions, and to some extent in studying the conditions for growth in established stands, the data collected by the United States Weather Bureau at its numerous regular stations may be used to good advantage. At the greater number of these stations only data on air temperatures and precipitation are obtained. At the larger stations data on humidity, sunshine, barometric pressure, etc., are obtained, but because of the almost universal location of such stations in towns and cities the applicability of the data to forest conditions is often very questionable. It appears, therefore, that the regular observations of the Weather Bureau will furnish us principally with precipitation and temperature data by which the broader forest regions may be de-

fined. The use of these same data in strictly local studies will depend entirely on the minute examination of the conditions surrounding the station.

KNOWLEDGE OF EXISTING WEATHER BUREAU STATIONS NECESSARY.

Before attempting any meteorological observations the investigator should visit the nearest permanent meteorological stations and obtain a clear understanding of the manner in which the observations are made, compare his own instruments with those of the station, and ascertain the natural conditions in which the permanent station is located and the extent to which they are typical of the region. This is essential to enable the investigator to decide whether and to what extent he would be justified in connecting his special meteorological observations with those of the permanent station. Observations at permanent, well-equipped Weather Bureau stations are not always conducted in the way that meets the special needs of the investigator. There may be observations essential to the forester which are not being made at all. Furthermore, the data of the permanent station will not always enable one to judge of the effect of the climatic conditions upon forest vegetation. For instance, the measurements of the temperature of the air are always made at a regular Weather Bureau station at some height above the ground and in a more or less open place outside of the forest; while to the forester, the temperature of that layer of the air in which most of the forest vegetation is found has the greatest significance. Again, while a very precise measure of precipitation may be of no use to the investigator, the amount falling in single storms may vary so greatly in short distances that a record obtained a few miles away will be very misleading. It is thus evident that forest research has special meteorological problems, and that usually the long-established weather station may serve better as a control than as a definite point for obtaining information about forest conditions.

COMPUTATION OF ALL WEATHER DATA BY PERIODS OF GROWTH AND REST.

One essential thing to be kept in mind is that plants may react to the climatic conditions in altogether different ways during periods of growth and rest. To analyze the reactions of plant life it is usually desirable, therefore, to compute climatic data by such periods. They may be based either on a knowledge of the particular plant formation which each observation-point represents, or on the average period of the native vegetation of the locality. Usually it will be preferable to adopt first a "growing season" for the whole region under study. Later, for more exact comparison of the component formations and after careful determination, the specific

periods of plant activity may be employed in summarizing temperatures, etc.

SPECIAL OBSERVATIONS ON CLIMATE AND SOIL OF LOCALITY.

To obtain concrete information on restricted localities and specific forest types it will be necessary in most instances for forest investigators to establish apparatus and make observations independently. In the more important respects the accepted procedure of meteorologists and the standard instruments may be used by the forest investigator, but the latter will also require many data not obtained in routine meteorological work, and, especially in the location of instruments, will be compelled to vary procedure according to local needs.

LOCATION OF INSTRUMENTS FOR THE STUDY OF THE GROWTH OF FOREST STANDS.

Atmospheric conditions affecting the growth of forest stands as a whole should naturally be measured at a distance from the ground which will represent the mean height of the sensitive portion of the tree: that is, the mean elevation of the crown. Thus, if a stand were generally devoid of green limbs for the first 10 feet of the stems and had an average total height of 70 feet, the observations

should be at $10 + \frac{70-10}{2}$, or 40 feet from the ground. Measurements

of the light received by the stand should obviously be made at an elevation where none of the light is intercepted. The same result may sometimes be obtained by measurements near the ground in a large opening on the same site. Soil conditions should be measured at all depths which the roots of the trees may be reasonably expected to reach. The depth will be less in heavy than in light soils. In general, however, it is believed that an extreme depth of 4 feet is sufficient, though any evidence to the contrary should change the procedure. The rule of measuring soil temperatures at the surface and at 1 and 4 feet may be followed. If it should appear necessary in using the data, the temperatures at other depths may be obtained by plotting the known values and by interpolating on the curve which may be drawn for any given period, assuming the temperature at 20 or 30 feet to be always equal to the local mean annual temperature. Similarly, soil moisture may be determined at the surface and at 1, 2, 3, and possibly 4 feet and, by projecting the curve formed by plotting the moisture of these points the moisture at greater or intermediate depths may be approximated.

LOCATION OF INSTRUMENTS FOR THE STUDY OF CONDITIONS AFFECTING REPRODUCTION.

It is only logical to assume that, before a definite plant formation or forest type can be developed, there must exist conditions favorable

to germination and development of the small and very sensitive seedlings. The forester is often concerned only with the problem of "securing reproduction," realizing that, once the seedlings of a given species are established, the future of the stand is quite definitely assured and practically beyond his ability to influence. In forestry particularly, because perennial plants are the subjects of study, the seedling stage presents the most acute practical problems and those most deserving of scientific study. What bearing this has on the methods to be followed in ecological investigations may be readily illustrated. If, for example, it should be noted that seedlings of a given species die in great numbers during their first or second winter and it is desired to determine why such losses occur and whether they are preventable, it might be deemed necessary to study the rate of evaporation and the amount of drying to which such seedlings are subjected during periods when the soil is frozen. Obviously, it would be necessary to determine this period precisely and to know (1) when the soil was frozen throughout the root zone of the seedlings, and (2) when it was frozen at the surface so that moisture obtained below might not reach the aerial portion. On the other hand, the atmospheric stresses and the tendency toward evaporation losses generally might be measured, that is to say, for the locality and at a convenient spot; but it would be apparent that if the seedlings under observation were covered by snow the rate of evaporation above that snow layer would have no significance whatever.

The point, therefore, needs the greatest possible stress that, in the investigation of many of the particular problems of reproduction and distribution of the species, the investigator must be concerned with the immediate conditions of the surface soil and the atmospheric and solar conditions at an elevation barely above the surface soil, in connection with germination, with survival before the seedling becomes well rooted, and with possible injury through heat or drought at the soil's surface before the young stem is protected by an effective corticle. Measurements at depths of even 1 foot in the soil, or at elevations of a foot above it, will usually only be made to give general, comparative indications of the conditions which it is really necessary to understand; and because the rapidly fluctuating conditions of the soil's surface are in many ways extremely difficult to cope with.

In considering the conditions which affect reproduction, an elevation of 6 inches above the surface may possibly be accepted as the lowest level at which aerial measurements are practicable, but by the exercise of ingenuity it should be possible to improve on this. In soil study, greatest attention must be paid to the near-surface conditions. The actual moisture of the covering of litter and humus, as well as that of the first mineral soil, is obviously important, but extremely

difficult to measure with any great accuracy, especially as the humus layer is seldom the same on any two spots which might be selected, and may change in moisture content almost as rapidly as the atmosphere. It is almost inevitable, therefore, that actual moisture measurements should be confined to the first layer of mineral soil and to greater depths if desired, and that the depth and character only of the humus should be noted, using some predetermined rule for estimating its moisture content at various times. For soil temperatures conditions at the surface are doubtless of the greatest importance; but here again the measurement of the actual and constantly changing soil conditions presents a practical difficulty. Measurements below the surface may have considerable comparative value, even though they do not give the extremes which may have the most direct bearing on plant life; and it is therefore suggested that a depth of 1 foot be taken in all such studies as furnishing a kind of control for other observations.

Having considered the general arrangement of apparatus, the matter of exact methods and instruments to be used in measuring each aerial and soil condition may now be taken up.

AIR TEMPERATURES.

Air temperatures are more readily measured than any other condition because of the simple equipment required, and they will probably be most frequently considered at temporary stations. It is hardly to be questioned that air temperatures affect growth very directly, although this may not always be apparent if only periodic and annual mean temperatures are considered. It is also fairly apparent that the air temperature which is adequate for the growth of an individual plant receiving an abundance of light may be quite inadequate for one growing in competition with or in the shade of other plants. Then there are the maximum temperatures to be considered, which it now seems may be more directly operative in preventing the extension of plant ranges than any other temperature condition. In this connection, the temperature of the soil surface may be most important, but that of the air layer just above the soil must not be overlooked.

The following problems summarize briefly what are believed to be the most important temperature problems in relation to forestry.

PROBLEMS.

1. Temperature zones, as indicated by mean monthly, seasonal, and annual air temperatures, or length of frostless season, or temperature sums (hour degrees) above a fixed minimum (say, 40° F.), which furnish the conditions necessary for the existence of a given species.

2. Actual rate of growth in height, diameter, volume, or weight of any species, within different temperature limits, should preferably be

determined under controlled conditions of moisture supply and sunlight.

3. Especially in connection with the preceding, and as integrating air temperature and sunlight influences, leaf temperatures should be measured as a more direct criterion of the temperature conditions regulating food production and growth. What is particularly sought, of course, is the relation between leaf temperatures, air temperatures, and sunlight, and whether or not this is essentially different in different plants. It is probably necessary to determine general relations of this kind and to base observations of growth on long-term air temperature records.

4. The maximum temperatures which may be tolerated without highly destructive reactions in the plant, leading to fatal results, have been investigated very little and apparently have received very little weight in considering problems of distribution, although a number of investigators have shown that growth-rate falls off rapidly beyond a certain optimum temperature. The difficulty of observations on this point lies in the extremely close connection which is likely to exist, under any natural conditions, between very high temperatures and excessive transpiration or positive drought in the soil's surface.

In the general study of climatic or temperature zones affecting plant distribution and life forms, Merriam's (30)² work has become classic. The more minute determination of forest zones may begin with comparison of mean temperatures or temperature sums above a minimum of about 40° F., or similar sums for the frostless period. Livingston (25), in a general survey of the temperatures of the United States, carried the matter one step farther by rating the chemical efficiency of temperatures above 40° F., according to the van't Hoff-Arrhenius principle of doubled activity for each 18° F. increase in temperature. These temperature efficiencies were then summed for the growing season, in place of the original temperatures. Sampson (32), McLane (31), and Lehenbauer (24), have tried various modifications of the Merriam idea of temperature sums, all of which should be looked into. One will hardly escape the conviction that the consideration of any temperature term other than the mean temperature will require the accumulation of hourly temperature records or, in other words, the use of the thermograph.

In the more exact study of the rate of growth as influenced by temperature a greater number of technical problems are presented. The temperature coefficient can not be determined unless moisture and sunlight are under control. The actual measurements of growth rate are difficult, and necessitate first of all plants of uniform age and size for the various comparisons. It seems to be quite well established that growth of most plants begins at about 40° F., is very slow

² The figures in parenthesis refer to the bibliography at the end of this bulletin.

up to about 60° F., and reaches a maximum at, perhaps, 80° F. These points will be at least suggestive of the temperature ranges and temperature groups to be considered. It will, however, probably not be satisfactory to merely note that a given growth was secured in A hours in temperatures between T and T₁. MacDougal (27) suggests the summation of temperatures from what may be called the base of each temperature range (say, about 60° F., but not more than 65° F.), and as the simplest means of obtaining hour-degrees in each temperature range has used the planimeter to measure the area on thermograph traces included between any two given lines.

The study of leaf temperatures is not a study of the environment, but will be at least a means to a better understanding of the action of the environment and will, perhaps, lead to more comprehensive and expressive measurements of the environment. A good deal of rough work has been done in measuring the temperatures of leaves, usually by wrapping them about the bulb of a thermometer or placing the latter in close contact with them. Such methods, however, are wholly inadequate for treating the needles of conifers, and are of doubtful value elsewhere. E. Shreve (36) has made use of the great sensitivity and possibly small bulk of a thermocouple, to devise an apparatus which will readily reflect the temperature of any part of a leaf with which it is brought into contact. The whole equipment seems sufficiently compact and practical to furnish great usefulness in the field as well as in the laboratory.

With this sketchy consideration of the problems which should be faced, the ordinary means of accumulating temperature records may now be mentioned.

EXPOSURE OF THERMOMETERS.

Comparisons of air temperatures under different conditions can, of course, be made only if the measurements are made in such a manner as to eliminate radiation influences. Radiation measurements or "sun temperatures" undoubtedly have their places, but are not to be confused with the present subject and they will be discussed later.

To measure correctly the temperature of the air, direct or reflected sunlight must be excluded from thermometers as fully as possible. At the same time, the shelter which affords this protection must not itself absorb the radiation sufficiently to become heated within. This danger is largely overcome by allowing free circulation of air through the shelter, and the danger is still further lessened when the air circulation is naturally strong. Such radiation is particularly to be guarded against in any kind of shelter placed on or near the ground. The standard type of shelter is double-roofed and has

a partly open floor, and walls made of slats which overlap to exclude light from any overhead source without causing complete stagnation of the air within.

Modifications which would still more fully overcome the heating of the shelter have been proposed by Köppen (23), who would provide artificial air circulation, but such provisions will hardly be necessary for any ordinary thermometric work. On the other hand, the observer can not be too strongly urged to provide shelters which will give the maximum of light protection without preventing the natural air currents from coming in contact with the thermometers. To obtain true nocturnal temperatures near the ground it may be desirable to use a shelter without a floor, so that radiation from below the thermometers is retarded as little as possible. In the work at the Fremont Experiment Station, Bates has found that a shelter for ground temperatures need be no more than a hood, fully open to the north and below the thermometers. If there should be considerable reflection from the north at midday, it could be largely eliminated by an absorbing screen set a foot or two from the hood.

STANDARDIZING THERMOMETERS.

The present possibilities of correlation between temperatures and plant behavior do not justify the greatest precision in thermometry. Units smaller than 1° may be ignored in field work, for all practical purposes, though personal taste may dictate that tenths of degrees be recorded. The essential thing is that only reliable thermometers be used, as the errors in cheap thermometers are not uncommonly as great as the difference between two conditions which are being studied. Even the standard types of maximum, minimum, and mercurial thermometers may well be critically examined and compared with a standard before being used. The Bureau of Standards (37) calibrates such instruments at a nominal cost.

With recording apparatus, such as the air thermograph, adjustment takes the place of standardization. The use of any such recorder, without thermometers to check its accuracy at frequent intervals, can not be recommended.

MAXIMUM, MINIMUM, AND CURRENT TEMPERATURES.

Where only maximum and minimum thermometers are available, of the standard Weather Bureau pattern, the maximum and minimum temperatures for the preceding 24 hours should be recorded once each day, either before 10 a. m. or after 4 p. m., and at the same time the current temperature, as indicated by the minimum thermometer, should be recorded, also the time of the observation. The current temperature is principally of value for making a thermograph correction, and the height of the thermograph pen should therefore be recorded at the same time.

When readings are taken in the morning, if there is no thermograph record by which the time of the maximum and minimum may be determined, the minimum then read should be tabulated on the form for "Air Temperature Record," as of the current day, and the maximum as of the preceding day. If readings are made in the afternoon, both maximum and minimum should be credited to the current day. The current temperature should, of course, be credited to the day on which taken. The instrumental corrections should be used when entering the data in the field, if cards therefor have been prepared, the card being tacked in a conspicuous place in the instrument shelter.

The daily range—purely a computed quantity—in degrees and tenths should be the difference between maximum and minimum temperatures as tabulated for any calendar day.

HOURLY TEMPERATURES.

Where a thermograph is available the instrument should be set in the same shelter as the maximum and minimum thermometers, and hourly temperatures may be obtained therefrom.³ Corrections for the thermograph trace should always be obtained from the readings of the maximum and minimum thermometer, as thermograph records are liable to considerable errors; but the hours to which these corrections are applied may well be a matter of judgment with the observer, depending on the shape of the temperature curve.⁴ The tabulation of hourly temperatures when obtained will require the special form, "Hourly (Air, Soil, or Actinograph) Temperatures." Certain data therefrom will be entered on the "Air Temperature Record." For example, as a measure of conditions affecting growth rate, it may be desirable to know, besides the mean:

³In any ordinary comparison of the temperatures of plant habitats, hourly temperatures are not likely to be used except to explain transient phenomena. However, the thermograph is an extremely valuable adjunct in determining the maximum, minimum, and mean temperatures, not only helping to correct errors of observation but making possible the more exact determination of the extremes and temperature ranges for any period, such as the midnight-to-midnight day, which is the unit of time in most meteorological computations.

⁴Various rules for applying corrections to thermograph traces are used by different students. It is obvious that errors may exist in the traces from two distinct causes: (1) When the range of oscillation of the pen is too great or too small the thermograph may read correctly at medium temperatures but be high and low at the two extremes; (2) even if the pen is approximately correct in its possible range there is a lag due both to the lesser sensitiveness of the thermograph as compared with a mercurial thermometer and to the friction of the pen upon the paper, so that normally the pen does not quite reach to the extremes indicated by the thermometers. In the first case, it is essential that the error be distributed somewhat according to the temperatures; thus, if the pen read correctly at a temperature of 45, at all temperatures above 45--the range of the pen being too great--there would be a minus correction for the trace, and at all temperatures below 45 there would be a plus correction. On the other hand, if the instrument is properly adjusted, it is logical to apply a minus correction to all descending portions of the trace and a plus correction to all ascending portions, the amount of such corrections to be determined from the corrections at the minimum and maximum, respectively.

[illegible]

¹ For air, entries in degrees and means in tenths; for soil, entries in tenths and means in hundredths; for actinograph, entries in degrees; no means.

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The number of hours with temperatures 32° or below.

The number of hours with temperatures 33° to 41° .

The number of hours with temperatures 42° or above.

FROSTS.

Since the actual freezing of foliage may have some very definite effects on plant functions apart from the temperature effect, the occurrence of frost on the ground in the morning should be noted and recorded at the time of regular observations. This notation is especially important in cases where air temperatures near the ground are not being recorded. If the latter are available, records of occurrences of 30° F. or below may be taken in lieu of frost observations. This record should also be tabulated on the "Air Temperature Record." It may be of value in determining at least a normal growing-season for some types of vegetation.

MEAN TEMPERATURES.

It is generally accepted by climatologists that the mean temperature for the day is sufficiently well represented by the sum of the maximum and minimum divided by two. This is probably less satisfactory in the forest, however, than in most open situations where insolation and radiation are not interfered with. Where a thermograph is in use, a nearer approach to the true mean may be obtained from the sum of the hourly temperatures divided by 24. Means for the day should be entered to the nearest tenth degree Fahrenheit. Some of the problems connected with computations of means are described by Hartzell (22).

The means for the decades and the whole month, in all temperature columns, should be obtained and entered to the nearest tenth degree. The following computations are suggested for valuable comparisons of growing conditions. They should be made and entered at the foot of Form 5. All should be taken from the maximum and minimum temperature records, since it is likely that some of the stations to be compared will have no hourly records.

Mean temperature for days with snow on ground.

Mean temperature for days with no snow on ground.

Number freezing days without thawing (maximum below 32°).

Number freezing days with thawing (mean 32° or below, but maximum above 32° F.).

Number cold days (mean 32.1° to 41.0°).

Number cool days (mean 41.1° to 50.0°).

Number moderate days (mean 50.1° to 60°).

Number warm days (mean 60.1° to 72.0°).

Number hot days (mean 72.1° or above).

ANNUAL SUMMARY.

The annual summary of air temperatures on the "Summary" form should be a tabulation by decades and months of the means or totals obtained from the "Air Temperature Record," with the annual mean or total, as the case may be, computed therefrom. Usually a separate "Summary" form will be used for each datum to be summarized.

In addition, as a part of the annual summary, there should be worked out the mean or total for each datum for the growing season. The limits of the latter may be determined, as indicated by the discussion in earlier paragraphs.⁵ Whatever the criterion as to the actual length of the growing season, it should be considered to begin and end with even decades, and all means computed for the growing season should be the sum of the decade means divided by the number of decades.

Form 10.

[U. S. Forest Service, Physical Survey.]

SUMMARY.

Type -----; station No. -----; datum -----;
height or depth -----.

Year.	Decade.	Month.												Mean annual.	Mean growing season.
		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.		

[Determined by comparing annual means for 1 foot and 4 feet.]

INSTRUMENTS.

Thermometers and shelters:

	Approximate range of prices.
Mercurial thermometer (Weather Bureau pattern)-----	\$1. 25 to \$3. 00
Maximum thermometer (Weather Bureau pattern)-----	2. 50 to 5. 00
Minimum thermometer (Weather Bureau pattern)-----	1. 50 to 3. 00
Maximum and minimum thermometers are often supplied in pairs.	
Support for maximum and minimum thermometers-----	2. 00 to 2. 50
Instrument shelter, complete, without supports-----	20. 00 to 30. 00

⁵As a matter of fact the temperature conditions that delimit the growth of plants, and especially of coniferous trees are not known, and to attempt to fix a rule for determining when the growing season begins and ends would, at this stage, be extremely arbitrary.

Recording instruments:

Thermograph, complete, with a year's supply of blank forms, pen and ink.....	\$70. 00
Combined air and soil (or water) thermograph, complete, with bulb and connecting tube 10 feet long; a year's supply of blank forms.....	105. 00
Extra length tube (above 10 feet) for above instrument.....per foot.....	. 50
Thermograph, short range of temperature (probably duty-free prices)	32. 00
Thermograph, large range of temperature (probably duty-free prices)	42. 00
Recording thermometers, dial type, with one or two pens and bulbs	\$75. 00 to 150. 00

SOIL TEMPERATURES.

Soil temperatures are probably even more important in forest study, especially when questions of initiation and distribution are involved, than air temperatures. Opportunities for obtaining data on the former will probably be more restricted, because of the greater difficulty and expense of installing satisfactory apparatus. They are at present measured at very few, if any, Weather Bureau stations.

It should be strongly emphasized that the study of soil temperatures is in a primitive stage, and that the devising of both instruments and methods offers great opportunity for the investigator, especially in the search for the exact, controlling conditions of the soil's surface. The present discussion does not attempt to consider all the special investigations which are undoubtedly needed, but confines itself largely to routine methods, by which a broader survey of soil temperature conditions may be gained, making possible regional and site comparisons on something like a standard basis.

PURPOSES TO BE SERVED.

The number, and to a considerable extent, the method of soil temperature observations to be made, will depend on the object. Some of the purposes to be served may be summarized as follows:

1. Rather general comparisons of temperature conditions in different plant formations and regions. For this purpose, soil temperatures may have some advantage over air temperatures, in that the former reflect to a considerable degree the amount of insolation received at the ground; and it must be admitted that air temperatures, without radiation measurements, really give no indications of the temperatures experienced by the plant. For this broad purpose, temperatures at a depth of one foot are perhaps most satisfactory.

2. Very careful comparisons of the extreme temperatures to which plants are subjected on the various sites. There is much reason to believe that maximum temperatures are often the forbidding factor in the extension of the range of any given species and that they react

mainly upon the very young seedling at the ground-line, where temperatures are usually highest. The proper investigation of this subject certainly demands surface measurements, but temperatures at a depth of a foot or more may give some indication of the surface condition. The actual measurement of surface conditions presents great technical difficulties, which will be pointed out later.

3. Determination of soil freezing, not as a directly operative temperature condition, but in relation to the availability of soil moisture. In this connection it must be borne in mind, of course, that soil moisture may become essentially nonavailable at a temperature as high as 34° ; and, again, that it may not actually freeze until a temperature of 30° or lower is reached. Soil temperatures for this purpose must therefore be coordinated with some data on the soil itself and on the plants involved. It is obvious that, to serve the purpose, frequent observations may be necessary. Continuous thermograph records are preferred because, while most forest trees are not sensitive to freezing for short periods, if at all, in the consideration of moisture even a short period of relief through thawing may mean the beginning of a new cycle of observations on the effect of drought. In the study of soil freezing, the surface or near-surface temperatures are perhaps most important, but it is not entirely certain that mere freezing of the surface soil will stop the movement of water through the main root and stem. It is the part of caution, therefore, to examine the entire root zone, and it may perhaps be necessary to know the conditions of the tree itself as regards freezing at a point near the ground line.

PROBLEMS.

The problems, then, to which soil temperatures are related, are even more numerous than those concerning air temperatures and involve more directly the relations with initiation, habitat extension, and plant succession, rather than rates of growth. Some of the most evident problems may be listed as follows:

1. Optimum temperature of the soil as a seed bed, in direct effect on rate and amount of germination.
2. Optimum temperature of the soil in stimulating osmosis in the roots and hence rate of growth.
3. Minimum temperature at which water is available, or sufficiently available to supply transpiration.
4. Temperature at which the soil freezes and cuts off the plant entirely from water, length of such periods, and atmospheric conditions conducive to transpiration during such periods.
5. Maximum temperatures of the soil or soil-surface which may be tolerated without injury to root or stem of the young, shallow-rooted, and barkless seedling.

6. Influence of air temperatures and light upon soil temperatures, especially maxima, with different kinds of soil cover.

7. Correlation between soil temperature and extremes of drought in the surface soil. It should be noted that the distinction between drought injury and heat injury to young plants is often very difficult, as is shown by Hartley's (44) work. Also, that the soil surface can not for long be excessively hot without becoming arid.

TIME OF OBSERVATIONS.

The daily range of temperatures at the surface of the soil may be considerably greater than in the air above, and for the study of surface conditions the thermograph is essential. The time of observation of thermometers used to check this instrument should be a time when radiation and absorption of heat in the surface soil are about equal, or, in short, in the early morning. At no other time will a real check be found possible, because the thermometer and thermograph are not equally sensitive to changes and do not absorb direct sunlight equally well.

The daily range of soil temperatures at a depth of 1 foot or more is so slight that it is unimportant, except in its bearing on the question of determining the mean for the day. The latter must often be obtained from a single daily reading of soil thermometers, and must be based on a knowledge of the diurnal oscillation for the particular site. The daily range at 1 foot will seldom, if ever, exceed 5° F., and at 2 feet it is far less; so that, at greater depths than 1 foot, almost any time of the day is suitable for obtaining approximately a mean temperature. The time of observations may therefore be made to accord with other observations without any serious disadvantages.

The point of this discussion is that it is not satisfactory merely to compare the soil temperatures of several sites for a certain time of the day, since at that time one soil may be cooler than the mean temperature for the day and another above the mean.

DAILY MEAN SOIL TEMPERATURES.

The simplest way to secure a proper comparison of sites in respect to mean soil temperatures would, of course, be to determine the maximum and minimum for each day and to average these, as is commonly done with air temperatures. However, as will be pointed out in the discussion of apparatus, registering thermometers for this purpose have not been satisfactorily developed; so that, at present, dependence for a complete record must be placed on one of the several types of soil thermograph, supplemented by frequent readings of a thermometer.

Granting that a full and satisfactory record of soil temperatures may be obtained by the use of the thermograph, it may still, because of the cost of this instrument, be impossible to obtain the desired comparison of a number of sites. The best alternative would seem to be to make one thermograph serve for a number of stations by placing it successively at the several stations until the nature of the diurnal oscillation, for a given season, has been worked out for each station. These oscillations will depend so greatly on the character of the insolation, that a curve for one point could hardly be expected to apply at any other point. With a mean daily curve, however, a single thermometer reading each day may give a very good basis for approximating the mean soil temperature for the day. If this is convenient, the reading may be timed to accord with the most probable hour for the mean temperature to occur.

With hourly soil temperatures for a period of a week at any season, tabulated on the "Hourly (Air, Soil, or Actinograph) Temperatures" form, the mean hourly temperatures may be computed, as well as the mean for all of the days concerned. From the former may be obtained a correction factor for any hour, which, added to the reading for a similar observation hour will give approximately the mean temperature.

For instance, a study of station A-1 at Wagon Wheel Gap, Colo. (steep northerly exposure), at midsummer, showed that the daily oscillation was about 1.35° , that the mean temperature was approached very closely at 7 a. m. or 7 p. m., the minimum not occurring until 2 p. m., and that the correction for a 9 a. m. reading, on 6 days, varied from $+0.10^{\circ}$ to $+0.50^{\circ}$, with a mean correction of 0.34. Similarly at station A-2 (south exposure), it was found, that the approximate mean would be read at 5 a. m. or 4 p. m., that the minimum occurred at noon, that the daily oscillation was 2.37° , and that a 9 a. m. reading must be corrected by -0.88° to give the mean for the day. Corrections for six individual days varied from -0.50° to -1.35° .

Moore (11) states that at a depth of 3 feet daily oscillations are not felt. It is believed that they are, as a rule, too small even at 2 feet to warrant consideration, although in excessively insulated soils the procedure described for 1-foot temperatures may be followed.

Another method which suggests itself for determining the probable variation from the mean of any daily temperature reading at a fixed hour is to compare the annual mean temperature at the shallow depth with the mean for 4 feet or greater depth where, it may be assumed, the daily values are not affected by regular oscillations. For, while at any time the deeper soil may be cooler or warmer than the surface, the deeper soil always evincing a definite "lag" when

changes are in one direction, still there is no basis for assuming that for whole years there can be any essential difference. Therefore, if, for example, the mean annual temperature at 1 foot, as shown by 8 a. m. observations, is 49°, and the corresponding temperature at 4 feet is 50°, there is every reason to believe that the 8 a. m. readings at 1 foot give values, on the average, 1° below the corresponding daily means. When the oscillations are greatest at midsummer, this correction would be too small, and in winter it would be too great; but its use should, at least, bring us nearer to the true mean temperature for any given period.

Table 1 indicates the correction factors thus obtained for a number of stations and sites, with sufficient description of each to show why the morning temperature is much or little below the mean for the day. Practically all of these records were obtained from thermometers in iron pipes, which, by conduction, tend to create a greater daily range of temperatures in their vicinity than occurs in the soil naturally. From these data it will be seen that a small variation from the mean is likely to be secured if (1) the aspect is easterly so that the site receives early insolation, or (2) if the observation hour is relatively late, or (3) if the natural daily range is small, as is usually the case with heavy cover and to some extent on slopes which do not receive vertical rays. Finally, insolation late in the day, though probably causing a large daily range, may bring a morning observation relatively high on the descending curve. These data will be principally valuable in indicating that every site must be studied independently.

TABLE 1.—*Probable error in mean 1-foot soil temperatures obtained through single daily observations.*

[Determined by comparing annual means for 1 foot and 4 feet.]

Site.	Station.	Average depression of 1-foot temperature.	
Moderate southerly slope open.....	F-1.....	2.92	8 a. m., strong radiation. ↘
Southwesterly slope, some trees.....	F-2.....	1.01	Insolation late in day.
Northeast slope, steep, heavy cover.....	F-3.....	0.71	Insolation early, range small.
East slope, some cover.....	F-4.....	0.34	Insolation early.
Canyon bottom, heavy cover.....	F-5.....	1.40	Insolation late, if any.
Northwest slope.....	F-6.....	1.17	Do.
North slope, no cover.....	F-7-8.....	1.10	9 a. m., some insolation early.
North slope, full cover.....	F-9.....	0.94	9 a. m., little insolation.
Flat, little cover.....	F-11.....	1.19	7-8 a. m., heavy snow blanket.
Do.....	F-12.....	0.78	8-9 a. m., insolated all day.
North slope, one-third cover.....	F-14.....	1.11	9 a. m., little insolation.
Do.....	F-15.....	0.97	Do.
North slope, high altitude, no cover.....	F-16.....	1.38	10-12 a. m., radiation intense.
Gentle easterly slope, little cover.....	M-1.....	0.64	8 a. m., early insolation.
North slope, steep, cover.....	W-A1.....	1 0.38	9 a. m., small daily range.
South slope, steep, some cover.....	W-A2.....	3.16	Great daily range.
North slope, heavy cover.....	W-F.....	0.34	11-12 a. m.

¹ This station equipped with telethermoscope, so that depression is due solely to normal depression of soil temperature at 9 a. m.

READINGS.

All readings of soil thermometers should be in degrees and tenths. Where suspended soil thermometers are used, the readings should be made with the greatest possible speed after removing the thermometer from its seat, and care should be exercised not to expose the thermometer bulb to the sun, even though it be encased. Thermometers on the surface of the soil should be read, if possible, without frequent disturbance of their contact with the soil.

With standardized thermometers the correction may best be applied before recording the reading; but if centigrade readings must be transposed to Fahrenheit, or the reverse, it may be best to make the instrumental correction and the transposition in the office simultaneously.

TABULATION.

The daily observations may be tabulated on the "Soil Temperatures" form. Where two observations are made in one day, both should be entered on the line for the day, with the mean for the day computed from each, and the average of the two computed means in a separate column. Where more than two observations are made, it will be best to enter all at their respective hours on the "Hourly (Air, Soil, or Actinograph) Temperatures" form, and to enter on the "Soil Temperatures" form the mean of all readings without any corrections, provided the three or more readings are distributed well between the times of maximum and minimum temperatures.

HOURLY SOIL TEMPERATURES.

Whenever the soil thermograph is used, or when eye observations are made at frequent intervals, the hourly values should be tabulated on the "Hourly (Air, Soil, or Actinograph) Temperatures" form. With the complete record, the means by hours as well as by days should be computed for any period covered.

In addition, from the hourly record, the maximum, minimum, and mean for each day (midnight to midnight) may be transferred to the "Soil Temperatures" form, in order that the mean may be compared with that obtained from thermometer readings, and that the daily range may be shown.

The application of corrections to the soil thermograph trace can not follow the same rules as are used with air thermographs, because of the difficulty of making corrections of the maxima and minima at the time. If the correction of the soil thermograph trace varies considerably in amount from day to day, the amount of the correction at any hour should be determined by its position with respect to the preceding and following correction hours. If the correction at, say, 9 a. m. is about the same from day to day, one correction may be

[illegible]

[illegible]

1 All entries in degrees and tenths.

* Use "Average" column only where two readings are made in one day. The mean at 1 foot should be the average of the two computed means, which, if both corrections for time were exactly right, would be equal, but which are likely to vary by a few hundredths. When more than two readings a day are made, enter on Form C, and enter here only the average of the three or more readings. If the 8th to 12th columns on the form are used for readings at 2 feet or more, the two columns marked need not be filled. The column "Average" will be used as indicated above, when two readings are made in one day.

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Surface.	1 foot.	feet.
No. days soil frozen, below 32.0° F.)		
No. days soil cold (32.1° to 41.0°)		
No. days soil cool (41.1° to 50.0°)		
No. days soil warm (50.1° to 60.0°)		
No. days soil hot (60.1° or above)		

applied to all the hours of the day which it represents. This implies, of course, that the range of the instrument has been adjusted before it is placed in service.

SUMMARY OF SOIL TEMPERATURES.

In addition to the means by decades and months, the "Soil Temperatures" form may show the number of days, for each depth at which readings are taken, with temperatures below 32° F. (frozen); with temperatures 32.1 to 41.0° (cold); with temperatures 41.1 to 50.0° (cool); with temperatures 50.1 to 60.0° (warm); and with temperatures above 60° (hot).

ANNUAL SUMMARIES OF SOIL TEMPERATURES.

The "Summary" form may be used for a summary of one or several soil temperature conditions, such as the mean temperatures by decades, months, growing seasons, and years, or the number of days of each temperature class in each month. In the case of surface temperatures, the mean and absolute maxima and the daily ranges are doubtless of great interest. As many forms as necessary may be used.

It may be found that a given soil temperature sufficiently delimits growth so that the occurrence of such a temperature marks the beginning and end of the growing season. This has been the idea in suggesting a division of temperature computations at 41° F. or 5° C., such a temperature being approximately the minimum for activity of lower forms of plant life, as shown by numerous experiments.

APPARATUS.

The most simple apparatus for measuring soil temperatures is the encased soil thermometer, having a stem of sufficient length so that the mercury appears above the surface of the ground when the bulb is at the desired depth. As ordinarily made, however, this thermometer is not only very expensive but is inadequately protected from exposure to the elements and to mechanical forces. For this reason it is not desirable for permanent stations, but will probably in many cases be useful where observations are temporary and light equipment is desired.

For permanent stations the most serviceable apparatus that has been thoroughly tried is an ordinary thermometer suspended by a cord in a 1-inch iron pipe, whose lower end may be sealed either by a cap or by welding. The latter is preferable where the pipe must be sunk to any great depth, since the welded pipe may be formed as a wedge and may be driven into position without seriously disturbing the soil. The pipe should, in all cases, be long enough to extend well above the ground and above any ordinary snow cover-

ing, and the upper end should be capped, the suspending cord being attached to the inside of the cap. A welded pipe may be driven in almost any soil if the upper cap is screwed on tightly, and a mallet is used in driving, or wood is placed between the cap and hammer used. An iron hammer directly applied will tear the cap to pieces in a few blows.

The conductivity of an iron pipe is so great that its use for soil temperatures at a depth of 1 foot or less introduces serious complications. Wood or porcelain tubes are therefore necessary.

A porcelain wall tube, such as is commonly used in wiring buildings, may ordinarily be obtained in lengths up to one foot or more at electrical supply shops.

For a relatively permanent installation of thermometers at a depth of about a foot, wood tubes turned and bored in a wood-working shop are very satisfactory. The tube should have some taper, and the lower end should be pointed, so that it may be driven into a smaller hole that has been made with a bar. A wood which does not split readily should be used. When completed, the tube

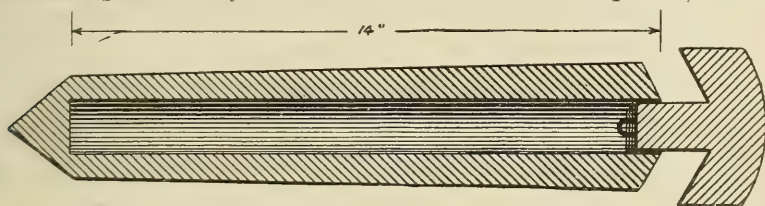


FIG. 1.—Sectional view of turned wood tube for soil thermometers at a depth of 1 foot. Telethermoscope (electric resistance thermometer) with one bulb and recording galvanometer \$245; extra bulbs, each \$15, connecting wire, per foot about \$0.10.

and its plug should be boiled and cooled in a bath of creosote and linseed oil, to prevent swelling, shrinking, and cracking. The top of the tube may be turned with a slope outward, and the plug similarly turned, so that rain water does not enter readily. A tube which has proven very satisfactory in Forest Service work is shown in figure 1.

A satisfactory tube for temporary use may be made by cutting a piece of 2 by 2 inch lumber 14 inches long, boring a 1-inch hole through from end to end, capping the lower end with a piece of tin, and cutting a plug to fit in the opening at the top. Two inches of the tube should be left above ground. It is hardly feasible to prepare this apparatus in greater lengths; in fact, for depths of 2 feet or more, the iron pipe is to be preferred.

In order to obtain reliable readings with a thermometer which must be lifted to read, it is necessary that the bulb of the thermometer be in some way protected from immediate contact with the air. This is done either by placing it in a cork, by wrapping it in

tissue paper, by sealing to the thermometer an empty cap or vial, or by sealing on a vial filled with alcohol. Covering the bulb, of course, retards the movement of the thermometer which changes of soil temperature, but this is unimportant as compared with the sudden changes which would result from bringing the naked thermometer up into the air. The thermometer to be used in these tubes should be the Weather Bureau "mercurial thermometer," and may be kept attached to the aluminum frame which affords much needed protection.

The use of registering maximum and minimum thermometers in soil temperature work is not very satisfactory. It is true that the standard Weather Bureau types of these instruments may be used on the surface of the soil almost as well as in the air. The following precautions, however, should be observed:

1. To bring the thermometer into close contact with the soil and to avoid unnecessary conduction the metal frame should be discarded.

2. The minimum registering thermometer should be protected from insulation in the middle of the day, since such thermometers ordinarily will not bear temperatures in excess of 120° F. Also, there is some tendency to distill the spirits and break the spirit column at high temperatures.

3. The thermometers must be nearly level.

Maximum and minimum thermometers of the ordinary type are not feasible at any depth, because they can not be kept level.

A maximum thermometer may, however, be used in a vertical position at any depth, provided the stricture of the capillary tube is sufficiently close to carry the weight of the mercury above it. This is technically almost impossible to accomplish, but one in a dozen maximum thermometers may serve the purpose.

To use the registering minimum thermometer at any depth, it is necessary that the stem be bent at a distance from the bulb approximately equal to the contemplated depth, and that the scale fall entirely in that part of the stem above the bend, which is to be horizontal. There is, of course, a limit beyond which this form of construction can not be safely carried, since the alcohol in the stem, as well as in the bulb, reflects temperature. An additional difficulty is in the distillation that has been mentioned, but this may be largely overcome by sufficiently high air pressure above the spirit column.

For permanent stations the use of the telethermoscope or electric-resistance thermometer may, in some cases, be advisable; but this apparatus is expensive and delicate, can not be installed except with considerable disturbance of the soil, and is subject to serious errors if, for example, the batteries become weak or the galvanometer is not perfectly leveled. Especially where great precision is necessary, as

in determining the character and influence of surface temperatures, the telethermoscope offers great possibilities.

The soil thermograph is desirable for continuous records of soil temperature which can hardly be obtained with any other instrument, and particularly for measuring the extremes, which it is almost impossible to obtain with registering thermometers. These can be had only after careful adjustment of the range of the pen, or by frequent checking against a thermometer, at high and low temperatures, after the instrument is installed. This instrument should at least be employed wherever new stations are being established, and until the daily curve has been worked out for each season. The securing of a record with this instrument is very similar in its routine features to the work with air thermographs. There is, however, one feature of the soil thermograph which deserves special consideration. This is the tendency, whenever the instrument is moved and the connecting tube suffers more or less deformation, for the whole apparatus to go through a gradual readjustment. One frequently finds the pen steadily ascending or descending for a week after any change. For this reason it does not appear practicable to calibrate or adjust the recording apparatus to agree with an accurate thermometer before placing the instrument and its bulb in their final positions. The Ecological Society, in outlining methods for a systematic soil temperature survey, however, recommended calibrating soil thermographs by placing the bulb in a pan of water with the thermometer, and after placing the bulb in its final position in the soil trusting completely to the accuracy of the thermograph.

It is believed, in view of what has been said, to be absolutely necessary to have a thermometer so placed in a wooden or porcelain tube that its bulb is at the same level and practically in contact with the bulb of the thermograph, and to obtain frequent comparisons of the thermograph and thermometer.

SPECIAL SUGGESTIONS ON SURFACE MEASUREMENTS.

It has been stated that the extremely high temperatures attained at the surface of a well-insolated soil seem to have an important bearing on the initiation of plants, and that technical difficulties make the actual measurement of this surface temperature almost impossible. Doubtless this could be accomplished from time to time with a super-sensitive plate such as constitutes a part of the leaf-temperature apparatus, but the problem of recording the maximum attained in a day or a season would still be unsolved.

It should be admitted, therefore, that a record of the maximum temperature at the soil's surface can only be approximated with present equipment, for the very simple reason that the object which

is to indicate the temperature can not be expected to react to insolation quite as the soil does, nor to be exactly in temperature equilibrium with the soil.

Since the technique has not been well developed, the following suggestions are made in the hope of obtaining somewhat comparable results by different investigators.

1. The bulb of the (maximum-registering) thermometer or the bulb of the thermograph should be exactly half buried, the object lying in a horizontal position. The lower surface may then be a little cooler than the surface of the soil, but the exposed surface may be a little warmer.

2. In order that the thermometer or thermograph bulb may have absorptive capacity for insolation similar to that of the soil studied, the exposed surface should be coated with linseed oil, and while this is still moist enough soil should be sprinkled upon it to form a thin coating. It may be necessary to repeat this at rather frequent intervals.

3. The thermometer or thermograph should be disturbed as little as possible, since, if the soil about it is kept loose, it will not be normally moist and will not have the temperature of undisturbed soil. A maximum thermometer of the ordinary type must, of course, be raised for setting, so that for frequent comparisons of thermograph and thermometer, the ordinary cylindrical-bulb mercurial thermometer may be most satisfactory.

4. Provision must be made for recording temperatures far in excess of those of the air or deeper soil. It will be safest to allow for an excess of full 100° F. over the 1-foot soil temperature, wherever direct insolation is received during several hours of the day.

INSTRUMENTS.

For mercurial thermometers, combined air-and-soil thermographs, and recording thermometers (equally adapted to air, soil, and water measurements), see "Instruments" listed under "Air temperatures":

Special soil thermometers, wood encased, with stem long enough to be read above the surface of the ground, for depths of 6 inches to 3 feet-----	\$6.00 to \$10.00
Soil (or water) thermograph, with connecting tube; pens, ink, forms, etc. (bulb is about 1 inch by 12 inches)-----	85.00
Soil thermograph-----	-----
Telethermoscope (electric resistance thermometer) with one bulb and nonrecording galvanometer-----	95.00
Switch for 6 thermocouples (Galvanometer requires about 3 dry cells)-----	16.00

SOLAR RADIATION—LIGHT.

The importance of light, at all stages in the development of trees, has never been underestimated by foresters. On the contrary, reviewing the literature of forestry at the present time, it would seem that this element of the environment has been emphasized, by some almost to the exclusion of all the other conditions. It was, perhaps, only natural that casual observers of the forest should mention this factor more frequently than all others, because the presence or absence of light is so easily detected. It must now be admitted, however, that visible light does not tell the whole story; and, furthermore, that phenomena, commonly called by foresters the "suppression" of trees, which have often been credited to insufficient light, may be and probably are in many instances caused by lack of moisture.

In this country Zon (77) citing experiments of Fricke, was one of the first to call attention to the relatively great importance of factors other than light. It may be that his suggestion created too strong a reaction, that there has been too much of a tendency on the part of American investigators to ignore light or to be satisfied with an incomplete study of its ecological relations. It is believed, however, that this is only apparently the case, the situation being explained by the large amount of ecological study that has been performed in the western mountain forests, where sunlight is not deficient and precipitation or soil moisture appears usually to be the more vitally controlling factor.

On the other hand, the work of Burns (56-59) shows substantial progress in the study of light. Its effects on growth have been directly observed, and its bearing on the transpiration rate and water requirements of young trees is, at least, strongly suggested. Pearson (12), Clements (60), and many others have made observations on light under less controlled conditions. The principal lesson to be learned from the progress to date, however, is that light can not be taken independently without regard for other conditions that it modifies and all of the plant functions which it stimulates. Nowhere, perhaps, is a better illustration found of the danger of one-sided ecological investigations than the common error of foresters in ascribing all bad effects of crowding in the forest to lack of light.

CONCEPT OF THE FUNCTIONS OF RADIANT ENERGY.

The solar radiation available to the plant not only supplements the heat available by conduction from the air but is vitally necessary to the chemical activities of the plant, of which photosynthesis is foremost and of most direct interest to the ecologist. It is fairly evident that sunlight has an influence on the temperature of leaves

and other plant parts of which we obtain only a partial measurement through ordinary air temperatures. That this is an important condition affecting distribution of every species is evidenced by the fact that with increase of both altitude and latitude, or, in short, with decrease of air temperature, a given plant seems to require more light for its development. This evidence is not in itself conclusive, because, on a given site, more light obtained by wider spacing will usually mean more moisture, which may often be the controlling factor. Again, in a given locality, the species which thrive best in air of low temperature always seem more tolerant of shade.

Perhaps it is best to analyze the situation at the outset according to physical principles and logic rather than on the basis of questionable evidence. The latter has been mentioned to forewarn the student of some of the pitfalls of poorly conceived observational methods.

The radiant energy available to the plant may consist of an infinite variety of rays or wave lengths, from the most subdued heat to the ultra-violet light. The effect of each of these wave lengths is entirely dependent upon the nature of the absorbants in the plant. Thus the organic material of the cell walls and the water within the cells are capable of absorbing readily the red and infra-red or "heat" rays of the solar spectrum. The chloroplasts show an ability to absorb visible rays, the proportionate absorption of the various wave lengths varying in different plants. Of the absorption of ultra-violet light by leaves practically nothing is known as yet on account of the difficulties of observation in this end of the spectrum. We may, however, safely assume a considerable absorption of these invisible rays.

There is practically no question that each of the chemical elements found in the plastids (or, for that matter, anywhere in the leaf cells) absorbs the kind of rays which it would absorb under any other condition. Thus the "selective absorption" by different plants may be mainly the resultant of different amounts and proportions of such of the elements as iron, sodium, and potassium.

All rays which are absorbed are heating, and all may assist in bringing about chemical reactions, of which the first in importance to the plant is the union of H_2O and CO_2 to form carbohydrates. The function of the chlorophyll and of the chloroplasts is to concentrate sufficient energy at a given point to effect this difficult combination. The kinds of rays which are essential to photosynthesis, therefore, are the kinds which the substances in the chloroplasts are capable of absorbing; and, as has been said, the substances may vary according to the kind of plant and according to the solutes which the soil is capable of supplying.

On the other hand, if the chloroplasts find themselves in a medium of cell sap which is cold, it is perfectly evident that the energy which has been concentrated in them through the absorption of a special assortment of rays may be dissipated to the surrounding medium by the simple process of conduction. The rate of conduction will decrease directly as the temperature of the cell sap approaches that of the plastids. It is thus seen that both radiant energy and heat of the air, which may serve to warm the leaf as a whole, do have an influence on photosynthesis; and that for a given intensity of sunlight there must be a leaf temperature below which photosynthesis can not be effected, because of the dissipation of the energy in the plastids. This leaf temperature will depend on every atmospheric condition, including the air temperature. The most important factor tending to keep the leaf temperature below the air temperature, is the use of any available heat in the water-vaporizing process of transpiration. This consumes a very large proportion of all the heat obtainable from all sources. The loss of water and consumption of energy is, presumably, to be looked upon as an unavoidable consequence of the need for stomata to admit carbon dioxide.

THE NATURE OF SUNLIGHT.

Biologists must enter upon the measurement of radiant energy, or even upon a discussion of the subject, with the greatest hesitancy, realizing (1) that the physicists' conception of energy is, at this writing, undergoing a change almost daily; (2) that investigations of the solar constant and of sky radiation have made enormous strides during the last two or three decades, creating a vast array of equipment none of which are of proven value, and leaving the whole situation in a state of flux; and (3) that these investigations have shown beyond question the constantly changing quality of sunlight, due both to variations in the sun itself and to absorption in the earth's atmosphere. Realizing these things, it must be admitted that the past investigations of light in connection with forestry and other biological subjects are, practically without exception, obsolete and of no assistance in looking into the problems of the future.

It can not be attempted in this discussion to predict the line of endeavor for future investigators in light. Plainly it is a problem for specialists only. A few of the most fundamental facts or principles which, it seems, must govern the method of attack at this time, may, however, be pointed out.

1. As to the character of sunlight, probably the most important point to be borne in mind is that it is an extremely variable quantity, both as regards its whole energy and its constitution of various wave lengths. Setting aside for the present the fact that the emanations from the sun vary periodically in total intensity and also in wave

length, it is necessary to consider the constantly changing absorption by the earth's atmosphere. According to Very (75), who cites Langley (Professional Papers of the Signal Service, No. 15), there are "two different kinds of selective depletion which the solar rays suffer in traversing the earth's atmosphere. One kind is greatest for the rays of shorter wave length, and diminishes by perfectly regular gradations as one passes toward the longer waves of the infra-red. Its cause may be referred to selective reflection or diffraction of the shorter ether-waves by particles of excessive minuteness. The other kind of absorption produces irregular gaps or depressions in the spectral energy curve, which begin at the red end of the visible spectrum and grow in magnitude and frequency as the wave length increases. Researches by Abney and Festing, and by other investigators, have traced the majority of these depressions to the action of aqueous vapor." In the extreme infra-red there is shown to be almost total absorption from this source.

The light, principally of the shorter wave lengths, which is diffused by minute particles in the atmosphere, is not entirely lost, but may be measured as skylight, probably of greater wave length than the original direct rays. The infra-red rays which are so greatly absorbed by the vapor of the atmosphere, merely heat the upper atmosphere, and to this extent, of course, are lost as solar radiation.

2. Looking at the matter from another viewpoint, and accounting for the rather regular daily change in sunlight intensity at a given point on the earth's surface, Kimball (63) after showing the greater intensity of all wave lengths at midday when the light passes through minimum thickness of atmosphere, makes interesting comparisons of the total and luminous radiation under various circumstances. Radiation from an overcast sky is slightly richer, and radiation from a clear sky markedly richer, in luminous rays, than is direct sunlight. Direct sunlight decreases in luminous richness as the sun approaches the horizon.

3. These few facts point to the uselessness of photometric methods, depending on the chemical action of rays of rather limited wave length, to measure the total radiation or any part of the radiation other than the few wave lengths which may be involved in the particular reaction. Thus, for example, even if it were assumed that silver chloride was decomposed in proportion to the intensity of a given section of the spectrum, a certain reaction with silver chloride might be secured with other wave lengths varying through a very wide range.

Again quoting Very (75), it is seen that photochemical processes are very complex and hazardous as a measure of energy:

While luminous effects may be regarded as dependent on a certain photochemical action upon the retina, not all photochemical processes are equally

definite and measurable. As M. Radau (72) says: "The red rays and the yellow rays in certain cases continue the work commenced by the violet rays, and in others undo what the last have accomplished. Thus, chloride of silver, slightly impressed by the violet rays, is then blackened under the action of all of the visible rays; and guaiacum, turned blue by the violet rays, is bleached by the more luminous rays. It follows that the chemical action of light is, in general, very complex, and that it can be used for measuring the energy of solar rays only with much circumspection."

The inevitable conclusion is that direct photochemical methods can not be made to solve the problems of ecology, but this does not eliminate spectrophotocchemical measurements, which may, in fact, give the best possible criteria as to the variations in the different spectral regions and the effect of such variations on plants.

4. The fourth point to be considered in approaching the study of possible methods for radiation measurements, is the difficulty of securing complete absorption of sunlight. While lampblack is popularly conceived to absorb rays of all wave lengths and to transform them into measurable heat, recent investigations have proved that this is only approximately true, and have shown the existence of an infra-red spectrum of extreme wave length to which lampblack is partially transparent. Fortunately, this region is relatively unimportant as a source of energy and may be, for biological purposes, almost wholly unimportant.

A greater source of error than that arising from the failure of lampblack to absorb the radiation is undoubtedly the loss, as heat radiation, and by conduction and convection, before the heat can be properly measured. It must, of course, be borne in mind that temperature is not a measure of heat, and that the indications of a thermometer can not be used except as the radiation rate of the thermometer itself has been thoroughly studied.

With this conception of the nature of sunlight and the difficulties in the way of its proper measurement, it is perfectly evident that the primitive methods that have been employed in measuring light in the forest do not give satisfactory results. Two distinct but supplemental lines of attack suggest themselves as being profitable:

1. The growing of trees under controlled conditions of light, using both artificial lights of known composition and monochromatic and other screens which will transmit to the plants only certain wave lengths, as suggested in the work which has been started by MacDougal (68): The physiological action of each wave length must, of course, be studied. Through such study it is hoped that the requirements for light may be determined, any actual deficiency in sunlight which exists in the forest recognized, and the effective supply measured.

2. In studying either the light conditions as they exist in the forest or the effective supply suggested by the preceding line of

investigation it is obviously necessary to use spectroscopic methods. Since the growth of a tree requires many years, and even complete suppression in the densest forest is seldom accomplished in less than two or three years, it is evident that in the forest minute examination of every variation in sunlight is unnecessary. An examination covering the entire period of the activity which is being studied must, however, be obtained. The nearly ideal and still practicable arrangement would seem to be provision for continuous observation of the total energy available as radiation throughout the period of plant activity, with sufficiently frequent spectroscopic observation of the composition of this energy to establish not only an average quality analysis for the whole period but also to show the variations which occur from season to season and year to year and their relations to the functioning of the plant.

Unfortunately, spectrum analysis by present common methods does not permit an examination of either the ultra-violet or infra-red spectra. For this reason it has been suggested that all spectrum analyses might be better conducted by means of energy measurements (e. g. thermal effect) than by optical comparisons. This is an almost unexplored field and presents infinite possibilities for the investigator who will devise a satisfactory method of measuring the energy of all parts of the spectrum under both laboratory and field conditions.

HORIZONTAL AND VERTICAL EXPOSURES.

It is perhaps well to point out at this stage that, particularly in forest studies, light measurements of whatever kind may be on two distinct bases. In forestry the growth of an individual tree is rarely spoken of, or even if it is, no practical significance is attached to it, because the individual can rarely be separated from the influence of other individuals. Forest growth, in any practical sense, must be growth (volume increment) per unit of land area. Similarly, if an attempt is made to find a relationship between growth and available light, it is certain that the energy must be expressed in terms of a unit of area inclined at the same slope as the ground. The total energy available to the crowns of trees on a northerly exposure of given gradient, for example, can not be more than that which would be incident upon a plane of exactly the same aspect and gradient. Land areas, however, are always measured in terms of their horizontal projections. It therefore follows that the measurements must be reduced to horizontal areas, and the simplest means for reduction is to expose a given area horizontally for the original determinations.

Determinations of total energy available for growth, however, will rarely be made in ecological studies, which are much more likely

to be concerned with questions affecting the survival of the individual plant or tree. The individual tree of any age must be thought of as a spherical, conical, or cylindrical mass of irregular surface, such that a pencil of rays will affect equal absorbing surfaces, almost regardless of its angle of approach. It is therefore logical that, in the study of individual trees, all determinations of light intensity and quality should take as the unit a pencil of rays of given cross section. This full cross section is to be obtained by exposing the absorbing surface of given area normal to the axis of the pencil.

In the following discussion exposures for this purpose and of this nature will be implied, unless light quantities affecting stand growth are specifically mentioned.

TOTAL RADIATION ON THE SITE.

To determine the quantity of radiant energy which is available for plants or trees on any particular site in relation to the growth of the whole stand, obviously the quantity should be measured at a point where it has not been intercepted or diminished in intensity. As previously pointed out, this will be above the crowns or in an opening of exposure similar to the plane of the forest canopy. After having determined the total amount of energy available, the amount actually utilized, if desired, might be measured as the difference between the total and that which is available below the canopy. In any event, the intensity of solar radiation may be expressed in heat units, or calories per square centimeter of horizontal area.

INSOLATION UNDER CANOPIES.

The measurement of insolation or sunlight intensity under canopies may be for two distinct purposes: To determine the amount of energy which has escaped the tree crowns above and therefrom to deduce the amount utilized by them; and to determine the amount which is available for undergrowth, either in the form of subordinate species or reproduction. The first measurement, which is not concerned with the tolerance of the species, but rather with the completeness of the canopy, the completeness of utilization, and the rate of growth of the stand should obviously be closely connected with measurements of total radiation on the site. Since the plan of such measurements has been explained, this subject may be dismissed and the attention turned to those problems which are concerned wholly with the question of tolerance, or the question of the relative requirements of the various species for light, especially in connection with survival in their earliest stages.

LIGHT MEASUREMENTS IN RELATION TO MINIMUM REQUIREMENTS.

The tolerance of trees to shade may be determined in any one of four ways:

1. By preparing empirical scales of tolerance, based on experience and long-continued observation of the relative shade-enduring qualities of various species when growing together. This method is obviously very crude, and may be very misleading, since such a condition as soil moisture may determine, as directly as does light, the relative positions of the species in any particular stand. The persistence of individual branches, or rate of pruning; the maximum density of stands composed mainly of any particular species; the ability of reproduction to thrive in shade; all these things may be considered in preparing empirical scales.

2. A second method of determining the tolerance of trees is by study of the structure of the leaves. Having determined the normal relations of the tissues of protective and assimilative characters, leaves may be subjected to different degrees of shading. Those which adapt themselves most completely to a variety of light conditions are naturally those which will survive best if placed under trying conditions as regards lack of light. This method, however scientifically it is executed, can not give us absolute comparisons, since the structures of leaves are so variable even under the same conditions that the exact degree of change of structure can not be determined. In other words, this may give indications, but not comparable statistical data.

3. A third method of determining tolerance is the experimental method, which must, of course, be executed in the laboratory where all other conditions, as well as the supply of light, may be controlled. The primary object is the determination of the minimum amounts of light which will sustain life of the several species under consideration, when all other conditions (especially heat and soil moisture) are nearly optimum. It will be fairly apparent, however, that high temperatures may reduce the light requirement, and low soil moisture may increase it; and, since variations in all of the other conditions will be encountered in the field, it is very desirable that any experimental test should be so conducted that the influence of these other conditions on tolerance may be at least accurately gauged, if not directly measured.

It is believed that the best results will be secured if each species to be tested is grown under a variety of light conditions, approaching both the optimum and the minimum, and if the tests are so conducted that the physiological effects of each light intensity may be expressed finally in terms of growth, or weight accretion, rather than if dependence is placed solely or largely on observations of

fatal effects when the minimum light has been exceeded. For example, if seedlings of a given species are grown with 20, 40, 60, 80, and 100 per cent of the full available light, other conditions being equal, and if the greatest accretion is put on by those having 60 and 80 per cent, while those having only 20 per cent barely exist, and some of their number succumb, it will be fairly evident that the optimum is between 60 and 80 per cent, and the minimum slightly below 20 per cent for the given conditions of heat and moisture. Both points may be found quite closely enough by curving the growth data. Similarly, in other temperature and moisture series different optima and minima of light may be found, and the absolute optimum combination may be very nearly arrived at.

On account of the difficulty of duplicating any set of conditions at different periods, it is extremely desirable that the more important species whose relative tolerance it is desired to know should all be treated during the same period, and also that an arrangement should be effected which will make possible different combinations of light with moisture and temperature.

The following plan for such experimental determination of tolerance, while merely suggestive, may assist in initiating some work along this very important line. The arrangements suggested should accommodate about four species. It would, perhaps, be well to run an initial test with rather gross differences in the light quantities, as suggested above, and to repeat at a later date when the knowledge obtained will permit more minute examination of the critical points:

Construct a solarium about $5\frac{1}{2}$ by 8 feet, with its long axis lying east and west, its floor and glass roof having possibly a gentle slope to the south. The depth from glass to floor need not exceed 18 inches. Divide this into three equal parts by means of glass partitions running north and south. If two layers of glass are used throughout, having dead air between them, the purposes will be more completely fulfilled without affecting light quantities appreciably more than would the single layer of glass. Let the higher north wall serve as entrance to the compartments, being closed by a door whose inner surface has very poor reflecting powers.

For each of these compartments 10 pans, each a foot square and 6 inches or a foot deep, will be required. These may be made of galvanized iron with drainage openings in the bottom. Into each pan put a measured quantity of soil, sufficient to fill it to within 2 inches of the top. The pan and dry soil weight both having been determined, the amount of water necessary to maintain a given moisture percentage in the soil may easily be computed, and this, added to the gross dry weight, will give the weight which the pan should show after each watering.

Each pan may now be sown with sufficient seeds of the several species involved to produce a good stand on the area of 1 square foot. Possibly 100 seeds of each species should be used in each, the

seedlings later being thinned to uniform density. Unless it is desired to determine the effect of light on germination, this process should be concluded for all pans, under uniform conditions, before they are placed in the solarium. The main operations may be started just as soon as the seedlings are established. Otherwise great care must be used to develop the seedlings similarly in all pans.

Having reached the proper stage, place 10 pans in each of the three compartments; say, in two north-and-south rows. The three compartments are to be maintained at different temperatures; say, at mean temperatures of 50°, 60°, and 70° F., with more or less diurnal oscillation in each. In each compartment one row of pans is to be given sufficient water to maintain its soil moisture at, say, twice the wilting coefficient, while the other row will be maintained at four times the wilting coefficient. The condition of the pans may at any time be determined by weighing and the water supply regulated accordingly. In any row of five pans five different light intensities may be maintained. One pan in each row should doubtless be allowed full sunlight, another should be cut 20 per cent, a third 40 per cent, etc. The amounts may be governed by previously gained empirical knowledge of the requirements, so that the full range of light values will not have to be covered in any case. The shading of each pan separately may be arranged by using covers of punched screen, in which the areas of the openings correspond to the proportion or full light which it is desired to admit. It should be borne in mind at the outset that the glass of the solarium considerably reduces the light intensity, particularly in the infra-red rays. The quality of this light should be compared with that of direct sunlight and means should also be devised for measuring the light intensity under each screen.

The proper heating of the various compartments will prove the most serious obstacle in most cases. This, of course, will have to be accomplished by artificial means and should be done by introducing warm air into the compartments from an outside source in such a manner as to maintain the desired air temperatures without directly heating the pans. The air thermometer and thermostat should be suspended at a mean elevation and protected from insolation.

The positions of pans in each compartment should be frequently changed so that none will profit more than others by localized heat and light optima which are certain to exist.

The final effect of light and also the effect of other factors with light is to be determined by the accretion of dry matter in the seedlings of each pan and species. In order that this may be expressed in net quantities for the time of treatment, some of the seedlings weeded out at the beginning of the test should be dried and weighed.

It is evident that this general plan might be followed in tests to show the effect of different kinds of light on growth, using monochromatic screens as covers for the pans instead of the punched metallic screens, or supplying different compartments of a dark chamber with various kinds of artificial light.

4. The fourth method of determining tolerance or light requirements is similar to that just described, but depends on the measurement of light intensities as they are encountered in the field, and the

correlation of such measurements with observations on the condition, rate of growth, etc., of the trees existing under the measured conditions. The great advantages of this method are that a great variety of light conditions may be obtained and maintained with little expense or trouble and that growth and health of the subjects may be studied through long periods and under natural conditions. One disadvantage is that a variety of light conditions is necessarily accompanied by a variety in the measure of other conditions the effect of which may be confused with the effects of light, and neither of the two sets of effects can be exactly measured and balanced against each other, nor, most of all, can they be controlled. A further disadvantage consists in variation of the amount of shading at any given point with different hours of the day and seasons of the year, necessitating long-continued observations to obtain any expressive results. These disadvantages, however, will loom up less formidably when we understand better what part of the radiant energy is really effective. As has been pointed out, the field method must go hand in hand with laboratory studies.

APPARATUS AND METHODS FOR RADIANT ENERGY MEASUREMENTS.

Although most of the methods of light measurement used by forest investigators have been described as now obsolete, it is impossible, of course, to throw away all that has been gained through experience with different types of instruments. Quite apart from forest investigations, there is available a vast amount of research in the study of light per se which, however incomplete and changing this study may be, represents the starting point for any new work undertaken. It is therefore considered expedient to bring together a list of the methods and instruments which have been used, not in any degree of historical completeness, but rather to show the several lines of study and their possibilities as briefly as possible.

1. In the *radiometer*, which is commonly seen in jewelers' windows, the energy of light is transformed into work. This instrument has no practical value, however, because the work is performed inefficiently and probably does not vary in proportion to the energy received.

2. The *thermopyle* represents the first attempt to transform radiant energy into electrical current. This is accomplished by allowing the light to fall upon the junction of two wires of different metals. The opposing ends of the two wires are also joined, forming a complete circuit. The amount of current generated and passing around this circuit is measured at any point in the circuit by means of a galvanometer. The radiomicrometer, for measuring the heat from stars, is an extremely delicate adaptation of the principle of the thermopyle.

3. The *bolometer* developed by Langley (67), who was a pioneer in investigations of the sun's energy, employs a blackened platinum strip for the absorption of the rays, the thermal effect on this strip being measured by its change in electrical resistance.

4. The later developments along this line, described as *pyrheliometers* are known, respectively, as the Ångström (69), Callendar (64), Marvin (65), and Smithsonian Institution Standard (50). The first three are constructed on the principle of electric resistance thermometers, while the Smithsonian utilizes a mercurial thermometer. The Callendar, it is understood, is distinguished by its automatic arrangements for constantly recording the difference in resistance between the absorbing and nonabsorbing plates or "grids."

The technical differences between the several types of instruments are so involved that a discussion of them can not be undertaken here. They have to do largely with questions of efficiency in absorption and measurement of the energy. In fact, the student of ecology who plans to use any such instruments as these will be compelled to make a most thorough study of the subject. Recent years have seen so much attention given to it by physicists and meteorologists that, it may be said, the measurement of solar radiation is in a state of flux. Bigelow (53) has recently questioned the adequacy of any measurements made with pyrheliometers, declaring them useless, at least for the determination of the solar constant. It will therefore be the part of wisdom for biologists to stand aside until the physicists have reached a more stable basis.

In all of these instruments the auxiliary apparatus required is considerable, except possibly with the Smithsonian. This is naturally a deterrent to their use in the field, although the difficulties may always be overcome when we are convinced of the usefulness of the results. An instrument utilizing a mercurial thermometer recommends itself for simplicity; yet, in view of the frequent changes in the light intensity at any single point in the forest, the equipment for continuous recording is not more than is needed for satisfactory results.

5. The *thermometric sunshine recorder* (70), with electrical registering apparatus, is the equipment used at many Weather Bureau stations for registering the duration of sunlight. This instrument is extremely simple in design and operation, involving only the movement of a column of mercury through a tube connecting a blackened and a transparent bulb of an air thermometer. When the mercury reaches a certain height, as the result of air pressure in the black bulb, it completes a circuit with the two platinum wires embedded in the walls of the tube, and the current passing over this circuit operates the registering mechanism.

The apparatus is adjusted by increasing or decreasing the amount of mercury in the tube and by bringing the tube closer to or farther from a vertical position, so that the mercury first reaches the platinum wires when the disk of the sun is visible through the clouds. Any addition to the light intensity above this approximate standard does not, therefore, alter the nature of the record. While the method is thus seen to be extremely crude, the record showing only the presence or absence of light of a rather low intensity, still it can hardly be questioned that such a record of sunlight duration is of very great value in comparing the solar climate of different regions, and possibly also in obtaining a measure of the direct light under canopies; that is, of the approximate degree of shading. There appears to be an untried value in such records through arbitrary rating of the recorded "sunshine" according to the elevation of the sun, and with allowance also for atmospheric humidity.

One objectionable feature of the instrument is the amount of time required to warm it in the morning to the point where it first records. In fact, it is by no means free from effect of the air temperature and must be adjusted to the seasons.

In the lack of a better measure of sunlight values, it seems well worth while to have this sunshine record in forest studies. The form for "Daily and Hourly Sunshine Duration" has been provided for the tabulations of a month.

6. The *solar thermograph* or mechanical differential telethermograph devised by Briggs (54) in the biophysical laboratory of the Bureau of Plant Industry, is in principle the same as some of the soil thermographs; but it is a duplex instrument, in which the temperature of one of the bulbs tends to compensate that of a second. One of the bulbs may be blackened and spherical, with a short tube, so that the bulb is rather easily held just above the case of the instrument, while the second bulb may be kept in the shade.

This arrangement permits the recording of the excess of temperature attained by the bulb in sunlight, limited by the natural radiation and by conduction, which will increase as the air movement increases. The reduction of air movement to practically zero, or the elimination of conduction almost entirely by the use of an evacuated glass case, would make possible the calibration of such an instrument so that the temperature difference between the bulb and the surrounding air might be directly converted into rate of heat absorption by the bulb.

As a matter of fact, an ordinary air and soil thermograph has been used by Bates (105) with a fair degree of satisfaction, to show the variations in sun heat from day to day, the disadvantage of the regular equipment being in the variable surface exposed to the sun at different hours by a cylindrical bulb.

[illegible]

⁴ With or without twilight corrections.

¹ With or without twilight corrections.
² Must be determined by observing actual times of sunrise and sunset at the instrument, through all seasons, computing therefrom the possible minutes of sunshine for each day. Morning and evening hours should be given full possible value when it is observed that the twilight periods were perfectly clear; otherwise may best be left blank. No twilight corrections to be made unless regular observation is possible.

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There is hardly any question that an instrument of this kind may be made to serve the present practical requirements of forest studies, for a measure of radiation intensity. It would be very desirable to have the necessary protection from air currents supplied, without intercepting some of the rays by a layer of glass.

7. *Photo-chemical photometers*.—The objections which have been raised to the use of chemical reactions as a measure of the sunlight intensity can not be overcome. In addition to the fact that the other rays may not vary from time to time in the same proportion as the chemically active rays measured, it is somewhat questionable whether the result secured, as in the coloration of a photographic paper, is proportionate to the product of the light intensity and the time.

In forest studies the photochemical method seems to serve one purpose fairly well, that being to obtain a measure of the density of the canopy. It is then assumed that the amount of light reaching the ground is to the total sunlight as the area of openings in the crowns is to the whole area; or, in other words, that the light coming through these openings is unaltered in its passage. While technically there is also light below the crowns, which has been transmitted through the leaves, and the photographic paper may be sensitive to the rays in this class, it probably does not introduce any serious error, considering the purposes for which such measurements should be used.

This crown-density determination should always be made by moving the photometer through as great a space as possible during the few seconds of exposure.

The Bunsen-Roscoe (55) unit of actinic light is the light required to produce on a standard paper a shade equivalent to that produced by the mixture of 1 part lampblack and 1,000 parts pure white zinc oxide. The details of the preparation of this "normal shade" and the "normal paper" are given by Zon and Graves (78) or may be obtained from the original citation given above. The object in mentioning it here is simply to show that it is possible to carry on photometric observations on a fixed standard.

Likewise, photographic-supply manufacturers have prepared a standard shade, and a standard paper for estimating light intensities. One of the best known of the "exposure meters" is extremely simple in operation. In one opening of a small disk containing the standard paper is exposed the standard color, a permanent shade. In a corresponding opening may be seen a fresh area of the paper. It is only necessary to expose this to the light until it attains the standard shade, noting the time required, to have a very close basis for computing the light intensity. It seems that this simple contrivance may serve the purpose of ecologists quite as well as more elaborate apparatus of the same type.

Weisner (76) used an instrument almost as simple as this, his standard shade and fresh paper being set in a groove in a block of wood, and appearing in openings of a layer of opaque paper.

Clements (6) devised a photometer in which a narrow strip of "solio" or other sensitive paper may be held, having sufficient area for 25 exposures. This strip is placed on the periphery of one metallic ring, which fits snugly inside another. In the outer ring there is an opening one-fourth of an inch square, covered by a slide which is drawn back to make the exposure. In using this instrument the colors obtained on exposure are not directly compared with a standard color. Rather, it is customary to make a scale of shades with each set of observations, consisting of, say, 10 exposures in full light, of 1, 2, 3, etc., seconds. In the later exposures, then, it is only necessary to keep within the limits of the "scale," and the time may be varied to secure the desired shade. If, for example, a 24-second exposure gives a shade corresponding to 7 seconds on the scale for full light, the relative value of the suppressed light is $7/24$ or 29 per cent.

The photochemical-photometer method is not satisfactory for any expression of the light in absolute terms, or for comparing quantities in one day or season with another day or season, or for comparing different localities. Of course, all exposures might be compared to some standard shade, but the operation is needlessly circuitous and is made the more difficult by the perishable nature of the record, the need for examining it in dim lamplight, etc. It is therefore believed that, while this method has some value, a similar effort expended in determining absolute light quantities will be much more profitable.

In addition to the above there are instruments of the same principle by which more or less continuous records may be secured. In one such instrument, used by the Weather Bureau a number of years ago, the light entering through a very small opening made its impression as a band across the sheet of photographic paper on which it fell at successive moments. (See Clements (6), p. 51.)

8. It is probable that several hundred kinds of *comparison photometers* have been devised, all depending on an ocular comparison of the sunlight to be studied, with a light of known luminous powers. It is evident that such instruments deal only with the luminous rays, and while they rely upon the accuracy of the eye, the method certainly has advantages over the photochemical method in dealing with that part of the spectrum which is least affected by changes in atmospheric absorption. It is not to be supposed, however, that the luminous rays control plant activities.

One of the simplest types of comparison photometers is the smoked-glass type used by Wagner and credited to him by Zon and Graves (78), although undoubtedly invented much before his time.

The smoked glass is in the form of a wedge which is inserted between the eye and the source of light, until the thickness attained by moving it one way or the other is just sufficient to cause complete absorption of the rays. The wedge is calibrated along its entire length, and the comparison is made between the modified light under study and the full, direct sunlight. Since the luminosity of the latter is variable, the results are not, of course, in absolute terms, even if the subjective error were eliminated.

The Sharpe-Millar (73) photometer is a more recent development and probably superior to other photometers using comparison lamps, in that the light is supplied by electric current, and the comparison lamp may be standardized as often as necessary by varying the amperage. Kimball (63), however, in using it through a great range of daylight values, found it necessary to have screens to cut down the intensity of the daylight to the range of the artificial light; also blue-grass screens to reduce the lamplight to the color of daylight (skylight) alone. It is thus seen that a comparison of sunlight with artificial light has various complicating factors, even with the best of photometers.

With certain correction factors arising from the use of these screens the distance of the comparison lamp from the photometric device is made to express directly the power of the illuminating source in foot-candles.

9. *Spectroscopic measurements.*⁶—In the spectroscope the rays of any light are separated according to wave length. This naturally makes it possible to note the presence or absence of those wave lengths which are known to be essential to the plants under consideration, so that spectroscopic observations promise much to the student of ecology. Unfortunately, however, with the ordinary spectroscope, observations must be ocular and confined to the visible or middle portion of the spectrum. Both the highly active chemical region of the ultra-violet and the strong heating rays of the infrared, are outside of observation.

Zederbauer (79) made spectroscopic observations of the light in the forest, from which he concluded that there is a marked difference between the absorption by pine and spruce, or intolerant and tolerant species, respectively. The former absorb more strongly near the red end of the visible spectrum; the latter more strongly in the violet region. While Zederbauer's observations and his attempt to reproduce the transmitted wave lengths separately by means of monochromatic glass plates, did not lead to any precise results, they

⁶ The present discussion is necessarily very sketchy, because it is largely suggestive of possibilities rather than actual accomplishments in ecological work. For a complete discussion of spectroscopy and its possibilities we must refer the reader to such a monograph as Baly's "Spectroscopy" (52).

are certainly suggestive of the need for spectroscopic measurements, if we are to determine with any degree of accuracy the kind of light available in the forest.

It is self-evident that the simplest means for examining into the absorption of various wave lengths by leaves is to examine the spectra of beams of light which have passed through individual broad leaves or layers of needle leaves, charting the marked bands of absorption, and comparing such charts with similar ones for uninterrupted sunlight. Likewise the spectrum of the diffuse light in the forest may be examined, while the spots of direct light which have reached the ground through large or small openings may be expected to show essentially the same character as light in the open.

Such observations, while doubtless of great value in gaining an insight into the difference between species, and representing the first work which one would naturally undertake in spectroscopy, have only limited value because of the difficulty in reducing the absorption evidence to quantitative terms. There would naturally be also a large subjective error.

10. *Spectro photographs*.—Photographs of the various spectra which may be examined in forest studies obviously have an advantage over mere observations in their permanency, and over drawings in their completeness. According to Baly (52), ordinary photographic dry plates are fairly sensitive to rays within the lengths 2,200 to 5,000 Ångström units, or from about the limit of the blue well into the ultra-violet. In the "orthochromatic" plates and films of commerce the tendency toward very rapid action in the ultra-violet region is suppressed by the use of dyes, so that the shades and tones of the visible spectrum are more clearly brought out.

Plates approaching monochromatic value have been prepared for several regions, the principle being in all cases to stain the plate with a dye which absorbs strongly the rays it is desired to bring out. Thus a red-colored dye may be used to bring out yellow and green. According to Baly (52) again, Abney succeeded in preparing a photographic emulsion which was sensitive in the infra-red to 20,000 Ångström units, and the solar spectrum was actually photographed to 10,000 Ångström units. Such plates, of course, are short-lived, being very sensitive to heat.

In addition, there are, more recently, so-called panchromatic plates, which have a very wide range of sensitiveness.

Until more is known as to the part which the infra-red rays play in the chemical activities of the plant, it would seem to be the part of wisdom, in spectrographic observations, to use several plates, covering the entire range of the spectrum with as great thoroughness as possible.

11. Finally, in following out this line of thought, the *spectro-bolometer* represents the present limit of thoroughness. By measuring the heat energy of every part of the spectrum, all of the results may be expressed in the same absolute terms, whereas the results obtained by photochemical reactions must be in different terms for each of the several reactions which are required to cover the spectrum. Furthermore, bolometric observations permit the comparison of deficiencies in any region with deficiencies in the whole energy of the light as determined by the same means. As has been pointed out, the heat energy in the region of greatest chemical activity is small; but it is not too small for precise measurement, and when once measured it may be transposed to terms of definite chemical reactions, the transposition factor varying, of course, with each wave-length and with each reaction considered.

The Langley bolometer has been briefly mentioned, because it was designed for measurements of the whole energy of sunlight. The following description from Baly (52) indicates the manner in which the same principle was adapted to the most minute quantities.

In his final work upon the solar spectrum, Langley made use of a new apparatus⁷; the light from a 20-inch siderostat passed through the slit of a horizontal collimator, which possessed a lens of rock salt 17 centimeters clear aperture, and 10 meters focal length. This lens focused the ray upon a prism or grating; the prism was of rock salt, and was 18.5 centimeters high and 12 centimeters deep in the face, and had a refracting angle of 60°. The angular width of the bolometer thread was decreased to 2 inches of arc by using a telescope lens of 5 meters focus; the sensitiveness was thereby increased, and by improvements in the galvanometer the apparatus was made capable of detecting a temperature change of 0.000001° C. The whole spectrometer was of the fixed-arm type, and the spectrum was made to pass over the bolometer strip by rotating the prism. An automatic self-registering method was adopted of recording the galvanometer readings. The spot of light reflected from the galvanometer mirror was focused upon a broad strip of photographically sensitive paper. This paper strip was caused to move slowly in a vertical direction, and in this way a faithful record of the excursions of the light spot was obtained. At the same time the prism was slowly rotated, and therefore this record clearly showed all the temperature changes of the bolometer as the spectrum passed over it. Further, the motions of the sensitized paper and the prism were exactly coordinated, so that the angular position of the prism corresponding to any portion of the galvanometer record could at once be obtained. In this way, since the dispersion of the prism was already known, the wave length of any spectrum line shown upon the record could be found, and also, from the length of the throw of the light spot, its intensity estimated. The delicacy of this apparatus was sufficient to show the D lines widely separated, with the nickel line in between. * * *

By means of this apparatus, Langley mapped the solar spectrum as far as 55,000 Ångström units, and observed 700 lines between A and this limit.

12. *Evaporimeters* may be used for a very rough measure of the heating value of sunlight. At first thought it would seem that the rate of evaporation would be an almost ideal measure, since the

⁷ Brit. Ass. Rep., 1894, p. 465; and Nature, 51, 12 (1894).

evaporation of a gram of water requires a nearly constant amount of heat, varying according to well-known laws. The use of evaporimeters, however, has many complicating factors, principal among which is the air itself as a source of heat. If the atmosphere is lacking in moisture and the wind movement rapid, even an evaporimeter in the sun may be cooler than the air and consequently derive heat from the air. On the other hand, when the rate of evaporation is slow, the evaporimeter may be superheated, and some of the radiant energy absorbed will be dissipated into the air by radiation.

The situation is by no means simplified by the use of a pair of evaporimeters, one of which is designed to absorb little of the radiation and the other much or all of it. In this combination, one instrument may be giving heat to the air, and the other has heat conducted to it.

It therefore appears that evaporimeters may only give the broadest possible comparison of light intensities, as, for example, when a number of similarly constructed instruments are exposed to similar atmospheric conditions. The latter, of course, are very likely to be modified by the same factors that modify the light. For these reasons, the method can not be recommended as an aid in the study of present problems.

INSTRUMENTS AND APPROXIMATE COSTS.⁸

Angström pyrheliometers	----
Callendar pyrheliometers	\$500.00
Marvin pyrheliometer—not on market. (U. S. Weather Bureau) ..	----
Smithsonian pyrheliometer (mercurial thermometer). (Smithsonian Institution)	100.00
Sharpe-Millar photometer	100.00
Clements photometer	7.00
Exposure-meters. (Photographic supply houses.)	1 to 5.00
Spectroscopes	20 to 100.00
<i>Thermometric sunshine recorders:</i>	
Sunshine recorder, electric, glass (not filled), G. S. S. No. 12252	3.55
Electrical sunshine recorder, complete	37.00
Extra glass parts, mounted in brass socket, ready for attaching to support	23.00
<i>Registering instruments for use with thermometric recorders:</i>	
Two-magnet registers—	
No. 1. For sunshine and rainfall (using Form No. 1015-B)	140.00
No. 2. For wind velocity and sunshine (using Form No. 1015-C)	125.00
No. 4. For wind velocity, rainfall, and sunshine (using Form No. 1015-E)	140.00
Quadruple register complete (for wind direction, wind velocity, rainfall, and sunshine), with a year's supply of blank Forms 1017, pens, and ink	350.00

⁸ These should not be taken as quotations.

PRECIPITATION.

Precipitation should be measured at as many special stations as possible, but only at those which are fairly permanent. In general, the regular Weather Bureau data collected at a large number of stations will suffice for the purposes of forest investigators. Because of the difficulty of obtaining an average exposure under canopies, precipitation should always be measured in more or less open situations, or above the crowns, except of course when it is desired to determine the amount intercepted by crowns (89).

Since precipitation has no important action on plants until it is added to the moisture of the soil, there can be no object, in a biological study, and especially in a study of forests, in analyzing precipitation data very closely. For this reason there is no need of hourly precipitation records except possibly in a few localities to study the general character of the storms, which, of course, will vary only slightly with the forest types. For this purpose the tipping-bucket rain gauge (93) should be used. Standard eight-inch rain gauges (93), if properly exposed, will serve in most cases, though more valuable results will be secured where it is possible to install shielded gauges. On the whole, however, the gain in catch through the use of the Marvin shielded gauge⁹ is hardly of enough significance to justify the additional expense of the installation, at least for any practical benefit to ecology. The methods of measuring precipitation are too well known to need description.

Under certain circumstances, as in situations which can not be conveniently visited every day, it is possible to increase considerably the value of the record by keeping some kerosene in the rain gauge, which will cover the water and in large measure prevent its loss by evaporation. In this event it will be desirable either to pour off the kerosene before attempting to measure the water or to pour both into a glass graduate in which the amount of water can be seen in a few moments, after which as much of the kerosene as possible may be replaced in the gauge. This method needs little modification for the winter period, if the snow is melted before measuring, as ordinarily it would be. It is, however, very desirable to have the snow, as it melts naturally, drop into a seamless basin containing some kerosene. This may be accomplished by placing a loose funnel near the bottom of the gauge.

EXPOSURE OF GAUGES.

While the measurement of precipitation in gauges is very simple, the securing of a true "catch" is much more difficult, and for this reason the greatest care should be used to install gauges in such

⁹ Designed by the present Chief of the United States Weather Bureau.

positions that a near approach to a true catch will be secured. Wind (81) is the factor which usually prevents all of the precipitation of a given area from entering the gauge and which sometimes removes snow from the gauge after being caught. To obtain protection from wind without obstructing the fall of precipitation from any angle, should be the chief aim in the installation of gauges. The ordinary rule is that the edges of the shielding objects should be at an elevation of 30° or less from the edges of the gauge. This rule may be varied somewhat. Where precipitation is usually accompanied by high winds, the angle should be even less than 30° , and the shield, to compensate, must be the tighter. Where precipitation is not so likely to be driven by wind, the angle may safely be greater. A solid shield is less valuable than a partial one, because it may set up eddies in the air currents which will be fully as unfavorable as the direct wind. On the whole, shields consisting of trees or brush are best.

SNOW DEPTHS.

The depth of snow and its water equivalent will serve a useful purpose in giving data on the period of dormancy for each forest type, and in indicating the amount of precipitation available at the beginning of the growing season, which in some localities may be the larger part of the precipitation for the whole year (82, 88). The period of dormancy might be obtained more exactly by temperature measurements, but the latter are not possible at present at least on so large a scale. No data that can now be obtained will cover the forest types of the mountain regions so completely as the snow depth records, and the conclusions which may be drawn from them, as to the water supply, will be extremely broad and comprehensive.

SNOW SCALE READINGS.

The work of obtaining snow depth and density measurements by the national forest ranger force, and in cooperation with the Weather Bureau, is already well organized in some localities, and this work is of a nature which may be done creditably by the general forest forces. The same organization may possibly be effected with profit in other localities. While the work was originally designed to furnish data on the water available for stream flow and with that object in view has been discontinued at the end of April each year, there is no reason why it should not be slightly extended so as to serve the purposes of any forest investigations.

The general plan of the work is:

1. To have a large number of snow scales distributed over all the main watersheds and throughout the entire range of elevations and

the entire range of types, read at the end of each month by the rangers on whose districts they are located. The major portion of these scales are in timbered areas because of the necessity of some protection to secure a representative snow cover (90). Many of them, however, are not actually in the forest but in small parks or openings, and some are in patches of aspen or coniferous reproduction. The cover conditions are classified as (a) normal forest cover of mature or nearly mature trees, (b) partial cover, as given by aspen, reproduction, or scattered trees which shade the snow to some extent, and (c) no cover, as in parks or openings. For each snow scale a complete description of the cover and surroundings is obtained. The essential features of this description are listed on the record card for each scale, and the cards are filed serially according to scale numbers, each card carrying the depth and density record for 12 years.

2. The reports from rangers are submitted at the end of each month on postal cards, of which the following is a sample:

SNOW SCALE NO. —.

Snow Report ——— *National Forest, for the end of* ——— 19—, *county*
———, *main drainage* ———, *local stream* ———.

Depth at scale, ——— inches. Average in vicinity, ——— inches.

Is depth more (+) or less (—) than normal for this time of year? ———

Density measurement: Depth of snow in tube, ——— (inches and tenths);
water equivalent of tube contents, ——— (inches and hundredths, as shown
by spring balance).

*Density estimate, ——— per cent. (Light, fresh snow should be estimated at
6 to 8 per cent; settled, dry snow at 8 to 15 per cent; drifted, compact snow
at 15 to 20 per cent; frozen or wet snow, with ice at bottom, at 20 to 40
per cent.)

The above observations were made by ——— ("myself" or name of other
party) on ——— 19—.

(Signature) —————,

Forest Ranger.

*Not to be filled by officers having density apparatus.

3. Snow depths are read at each scale by simply sighting over the general surface of the snow and noting the intersection of this plane with the graduations on the scale.

4. For most localities, the density of the snow is estimated from the descriptive data given on the card. Each ranger is expected to make occasional rough tests to determine density, so that he will become proficient in estimating under varying conditions. A few rangers are now furnished with density-measuring apparatus (91) and the number of such apparatus is to be increased as conditions and funds warrant. The apparatus consists simply of a tube in which a core of snow may be taken (its length being noted on the scale outside the tube), and a balance graduated for inches of water. The weight in inches divided by the depth in inches gives the density.

Where density is estimated, the depth and density are entered when the report is received, and the water equivalent may be computed at any time. Where density apparatus is used, it is necessary to compute the density and apply this figure to the depth reading at the scale, which may be somewhat different from the depth noted on the tube.

It is self-evident that, while the progress of snow accumulation throughout the winter is interesting, the most important data are those which show the maximum accumulation just prior to the beginning of rapid spring melting.

TABULATION.

The form for "Daily and Hourly Precipitation" may serve as a monthly summary both for daily observations and for notations from hourly records where these are obtained. The following should be tabulated from daily observation:

Total precipitation in inches of rain or melted snow.

Unmelted snow, as measured in the gauge, in snow bins (84), or on the ground. Precise measurements of the snowfall appear to be useless to the ecologist.

Depth of snow on the ground at time of observation.

Number of storms of rain, sleet, or snow which, by the weight of accumulated water or because of accompanying wind, do mechanical damage to trees.

The following data are merely intended to depict the character of storms, and should be obtained from the hourly automatic records for a few stations typical of the different regions and altitudes:

Number of hours having measurable precipitation.

Number of hours having 0.05 to 0.10 inches precipitation.

Number of hours having 0.10 to 0.20 inches precipitation.

Number of hours having 0.20 to 0.50 inches precipitation.

Number of hours having more than 0.50 inches precipitation.

The "Summary" form will serve as an annual summary for precipitation data of both classes and will include all of the data given as the monthly sums or means on the several "Daily and Hourly Precipitation" forms. As usual, sums and means should be computed for the growing season as well as for the whole year.

INSTRUMENTS AND APPROXIMATE PRICES.

Rain and snow gauges:

Rain and snow gauge, 8-inch Weather Bureau pattern--	\$5.00
Supports, box, for rain and snow gauge-----	1.50
Measuring sticks, rain gauge, cedar, No. 12236-----	.15
Rain gauge, tipping-bucket, with supports and measuring tube-----	75.00

[illegible]

Enter on midnight to midnight basis where automatic records permit the division.

2 Gauge catch, unless mats or other reliable apparatus are used on the ground.

² In decade and month lines give the mean, not total.

* Since probably more than 1 storm a day will seldom occur, the extent of damage may be indicated in this space by the terms slight, moderate or severe, and the nature of the storm by the words, rain, wind, sleet, or snow.

Prepared by—

SOIL MOISTURE AND SOIL QUALITIES.

The subject of soil moisture is closely related to that of precipitation. Since the physical and chemical properties of the soil are closely linked up with moisture, it seems logical to consider all of these subjects together as a question of water supply, after which atmospheric conditions which particularly affect water losses may be taken up.

There is practically no question that water is the prime requisite of all life, for without water the colloids could not exist. It is hardly more true of plants than of animals that, besides possessing water at any given time, they must be almost continually given new supplies to make up for unavoidable losses; but, with the exception of aquatic species, plants are more at the mercy of the moisture of the habitat than are animals, because they can not move to new supplies—the water must somehow be brought within their reach.

Ecologically, it is perhaps unsafe to say that moisture has more to do with the establishment, development, and succession of a plant society than any other condition, that is, that it controls the character of the plant society more directly. It is perhaps nearer the truth to say that when the temperature conditions are about optimum for a given plant or society, moisture determines success or failure almost absolutely. Yet this does not express the situation, for in a vast majority of cases the plant society must depend at all stages, but particularly at its initiation, upon a proper balance between temperature and moisture, especially as these are integrated in the condition of the surface soil.

In the last analysis all other environmental conditions react more or less on the soil moisture, and the best measure of their influence in this respect is found in a measure of changes in the soil moisture. It is readily seen, therefore, that the direct measurement of the soil moisture is of the utmost importance.

The moisture content of the soil, whether expressed in grams per kilogram of soil or cubic centimeters per cubic meter of soil, does not give directly a measure of the rate at which it may be obtained by the plant, because of the great variation in the moisture-withholding powers of soils. This rate is obviously very important whenever the atmospheric conditions are such as to cause heavy loss from the leaves, and may often determine success or failure of the individual plant and of the society.

OSMOSIS AS A FACTOR IN WATER ABSORPTION.

The rate of absorption is unquestionably dependent upon the simple physical process known as diffusion, which is commonly called osmosis when speaking of plants, since the mixing of the two liquids

is somewhat modified by a semipermeable membrane between them which, in fact, tends to make the diffusion one sided. Expressed briefly and without attempting to define the kinetic forces, if there is water on one side of the semipermeable membrane and on the other side a solute in water, there is a constant tendency of the molecules of water to move both ways through the membrane, while the molecules of the solute, being heavier and larger, do not so readily diffuse to the side, where they are deficient in numbers. On the other hand the presence of the solute on one side of the membrane evidently has the effect of suppressing the energy of the water molecules there, so that fewer molecules pass in the outward direction than are coming in through the membrane. This results in an accumulation on one side of the membrane, and, so far as the increasing volume here is restrained, gives rise to a pressure which is termed "osmotic pressure." Actually, the pressure must be due to the energy of the free molecules which bombard the membrane from the outside.

In the case of the plant, there are, in addition to the mineral salts and organic compounds which may be in solution within the root-cells, and within each succeeding cell in greater concentration from root to leaf tip, two additional factors or forces, which undoubtedly have much to do with osmosis. While the forces may be called capillarity and adsorption, respectively, there is no reason for supposing that the action of these forces, so far as water molecules are concerned, is different from that of molecules of solids in solution. In other words, a molecule of a solid, whether acting individually as part of a relatively solid mass or surface or as part of a gelatinous mass like the cell protoplasm, by its gravitational attraction for a water molecule tends to suppress the activity of that molecule and thereby, under the proper conditions, gives rise to the process we call osmosis.

The so-called capillary attraction of the cell walls, which cause them to imbibe enough water to fill their intercellular spaces, can not be considered an important factor in osmosis, for ordinarily this attraction would pull the water as strongly from one side of the wall as the other. In the case of dead wood cells, it may be imagined that a small amount of water is transferred from one point to another through no other action than this capillary affinity of the cell walls.

The really important element in osmosis is, without question, the affinity of the protoplasm for water. While it appears to be true that a cell similar to a plant cell might have the same water content, arising from osmotic pressure and due entirely to inorganic solutes, still the important thing is, not merely that the protoplasm must have a certain minimum amount of water to maintain its properties as a colloid, but that through selective absorption it is able to regulate, at least to some extent, the nature of the solution which shall occupy the space within the cell. The protoplasm, while directly effective in

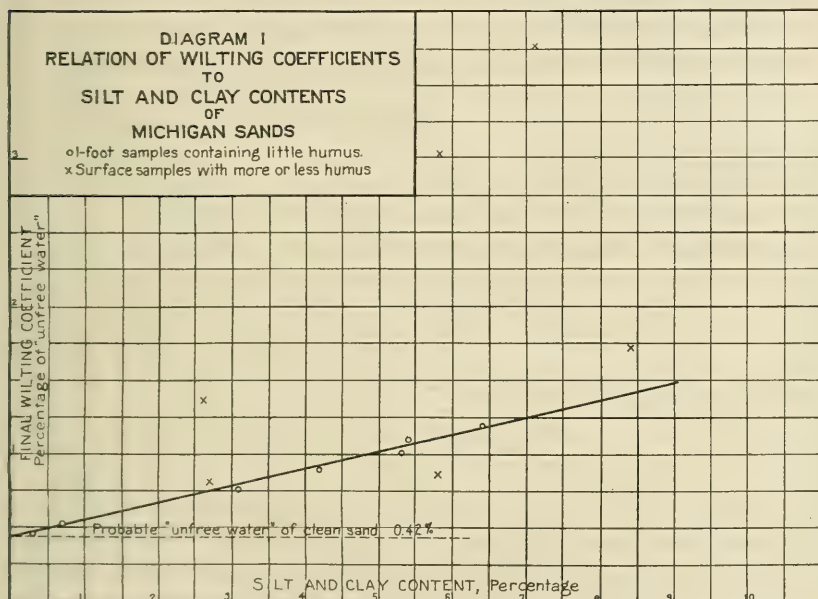
causing osmosis, is undoubtedly regulatory of all the conditions within the cell. It is, indeed, through the study of soils that the present conception of the nature of osmosis and of the importance of the colloids of the plant in this process is arrived at. The work of Bouyoucos (109) followed by Hoagland (127) has been especially instructive on this point. Bouyoucos and McCool (106) first attempted to determine directly the concentration of soluble salts in the soil by measuring the freezing-point depressions of soils in their natural conditions of moisture and with definite amounts of water added to them. At the outset, no doubt, he supposed that, allowing for increased solubility of the soil substances with increased moisture, the freezing-point depressions would increase proportionately as the concentration of the solutes increased by reduction of the whole moisture of the soil. This he found not to be the case, for, while the effect of increasing concentration was shown in greater freezing-point depressions as the moisture was reduced, a point was rather suddenly reached at which no freezing at all occurred. From this Bouyoucos concluded that there must be at all times in the soil a certain amount of "unfree" water, probably not in a liquid state but so adsorbed or chemically combined that at no time does it constitute a part of the soil solution. This water was conceived to be that which is held within the colloidal or clay masses of the soil, but it is fairly evident that, since pure sand may contain a small amount of such water, it may be in part water in extremely thin films, or more probably in the form of independent molecules, on the surfaces of the crystalline particles.

In his later work Bouyoucos (109) succeeded in measuring the volume of this unfree or combined water indirectly, by noting the volume expansion of the whole mass at the instant when freezing occurred. By this means he was able to determine just what proportion of the whole amount of water entered into the freezing process. Adding in every case 5 cubic centimeters of water to 25 grams of air-dried soil, he found that the proportion of this 5 cubic centimeters which did not freeze was only 2 per cent (0.10 cubic centimeters) in the case of a quartz sand, but 60 per cent (3 cubic centimeters) in the case of a clay, and 74 per cent for heavy silt loam.

The exact amount of unfree water for a given soil was found to be dependent on several experimental conditions, which led to the belief that under certain conditions it could be transformed into free water. In other words, there is no fixed point at which the water begins to be unfree, but under given conditions each soil exhibits certain definite characteristics. Thus there was in all soils, except the quartz sand, less water which failed to freeze when 10 cubic centimeters had been added to a standard sample than when only 5 cubic centimeters were used. There was also less when the supercooling was carried below the

standard temperature of $-4^{\circ}\text{C}.$, and when the process was repeated on the same sample several times. Without going further into these details, which are readily available in the original article, one more fact should be mentioned, namely, that the moisture contents at which various soils fail to show definite freezing points, and similarly the contents which by the method just described are found definitely not to freeze, bear a close relation to the wilting coefficients of the same soils.

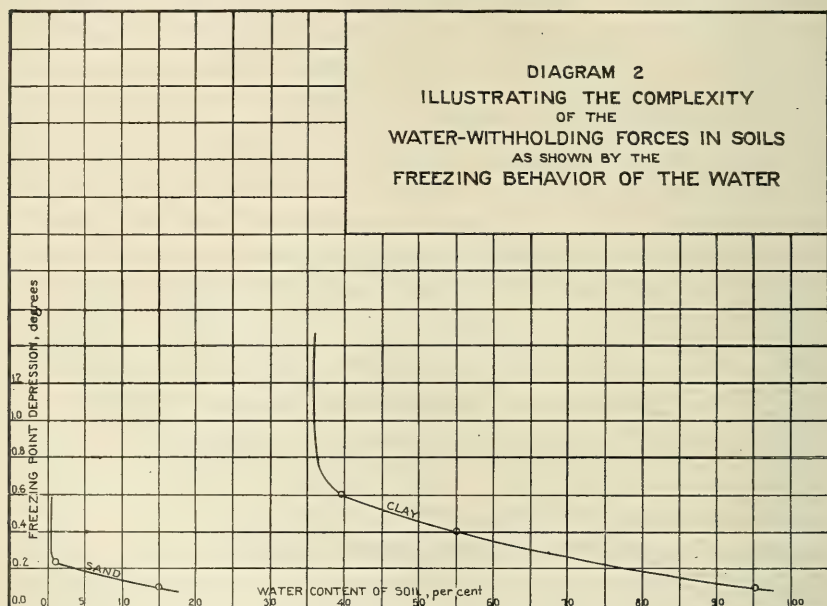
Directly bearing on the point as to the part played by the colloidal masses of the soil, Bates (105) found, for eight samples of Michigan and Nebraska sand, each taken at a depth of 1 foot, and consequently showing a maximum of 2 per cent humus, that there was a linear re-



lation between the final wilting coefficients for jack and Norway pines on the one hand, and the combined silt and clay contents of the respective soils on the other. The latter varied from 0.3 to 6.4 per cent. The behavior of surface soils with larger humus contents was different; but these, when decidedly lacking in humus, might give even lower values than the deep soils, probably on account of more thorough leaching. The results, as shown in diagram 1, indicate that if silt and clay were entirely eliminated, the sands might still possess a wilting coefficient of about 0.43 per cent. This is extremely close to the value for unfree water which Bouyoucos found to be almost constant in the case of quartz sand, regardless of the experimental conditions.

The conclusion is therefore reached that, in the final struggle which determines whether the plant shall obtain sufficient water for its

barest existence, there is a contest for water between two colloidal masses, either of which may be able to adsorb the solutes which have been in the water about them, and hence eliminate osmotic action in the ordinary sense of an interchange between two liquids. Apparently this contest between the attraction of the soil particles and clay masses on the one hand, and the cell walls and protoplasmic masses on the other, is not essentially different in principle from osmosis, except that in the final stage of the struggle the movement of a molecule of water from one side of the line to the other becomes impossible because of the lack of a liquid conductor. It is probably on



this account that, in a strong clay soil, the plant may wilt considerably before an equilibrium of tensions has actually been produced.

The important point, however, is that under normal growing conditions in the plant and soil there is a set of forces at work regulating the supply of water to the plant, which is dependent almost wholly on the presence of solutes in free water, or osmosis in the ordinary sense; while, when the water becomes relatively scarce (this may be at 20 or 30 per cent moisture content in a clay soil), an almost entirely different set of forces is brought into play. It therefore appears that the study of soil moisture is not so elemental as it has been supposed, and that the value of soil moisture to the plant can not be expressed by a direct linear function of the amount of water in the soil. Diagram 2 is inserted to show the nature of the problem. Forest investigators must get away from this elemental idea, taking up the study of soil moisture at the point to which expert soil physicists have already brought it.

PROBLEMS AND SOME DEFINITIONS.

Such being the general situation, it is evident that the ecologist has a number of related problems to solve before the measurement of moisture has much meaning. In the following paragraphs certain terms have been introduced which will have a rather definite usage in the later discussion.

1. The *total moisture* must be obtained as the basis for all expressions of current conditions in the soil, unless they are measured directly in terms which will give osmotic pressure.

2. The *nonavailable moisture* must be measured with reference to the plant or plants concerned, either directly by wilting tests, or through some established relationship between the *wilting coefficient* on the one hand, and the *antiosmotic pressure* (P') the *capillary moisture*, the *moisture equivalent*, or the *hygroscopic coefficient*, on the other.

3. The *available moisture* may be expressed as the difference between the total and the nonavailable moisture. Such an expression may have some direct ecological significance in indicating the probable duration of the moisture supply and the life tenure of the plants.

4. The *availability* of the moisture is seen in the general relationship between the available moisture and the total moisture, and may be expressed by a ratio such as 3:4, or by a decimal such as 0.75, on an unattainable scale of unity.

5. The *coefficient of availability* is a more exact expression of the relation between the osmotic pressure of the plant (P) and the antiosmotic pressure of the soil water (P'), and is a measure of the possible rate of intake. Thus, if the soil has a freezing-point depression of 0.5° , and the plant of 1.5° , the respective osmotic pressures are $P'=6.025$ and $P=18.04$ atmospheres, and the possible rate of intake is indicated by the difference, which is approximately 12.02 atmospheres. It is perfectly evident, however, that the osmotic pressure in the root tips may be very little greater than the osmotic pressure of the soil, while there may be a very great increase in passing from the roots to the leaf tips where water is being lost most rapidly. As this is also the most convenient point for measuring the osmotic pressure in the plant, and such can here be accomplished without seriously disturbing the plant, it is suggested that the osmotic pressure at the leaf tips should be the basis for expressing the plant condition. In this event, the actual availability of the water is obviously affected by distance, or the mean osmotic gradient from the soil to the leaf tips. The *coefficient of availability* (AA) must therefore be expressed by $\frac{P-P'}{L}$, in which L is the distance in centimeters from the root tip, or point of measuring the soil condition, to the leaf tip.

In addition, for the greater refinement of this expression, it will be necessary to make a correction for the height to which the water must be lifted. In small plants this would be of no consequence, but with tall trees it is evidently the factor which brings the coefficient of availability to zero long before the soil moisture is exhausted. This correction may be taken as approximately 0.097 atmospheres per meter of height. Expressing this whole correction by G ,

$$AA = \frac{P - (P' + G)}{L}$$

It should be noted that the availability of the moisture is an expression whose value will change only very gradually with the exhaustion of the soil moisture, and is really based upon an assumed equilibrium between the osmotic pressure of the whole plant and that of the soil at the time of wilting, which it is possible to attain approximately if the wilting of the plant is brought about very slowly.

On the other hand, the coefficient of availability must be constantly fluctuating, being dependent both on supply and demand (loss). Thus the rapid loss of a considerable amount of water from the leaves must be almost immediately reflected in the osmotic pressure there, the gradient from leaves to roots, and the rate of intake at the roots and of transfer from cell to cell. The objects in the use of such an expression must be to show not only how the demands of the plant vary from time to time, but how nearly the demands created by certain atmospheric conditions may be satisfied. Thus some insight is obtained into the conditions governing growth-rate.

6. There are various other conditions of the soil which have an effect upon plants and may or may not be fully indicated by the osmotic pressure of the soil solution at any time. Of these may be mentioned:

(a) The hydrogen-ion concentration as an expression of the degree of alkalinity or acidity.

(b) The make-up of the soil, and particularly its clay content as indicated by the mechanical analyses.

(c) Humus content.

(d) The capillary transporting power of the soil, by which water from distant regions may be brought to the roots. Obviously this may often be an extremely important factor in the economy of the plant. Its importance is somewhat minimized when moisture determinations are certainly made in the soil area which is reached by the roots.

(e) Chemical content of all elements and compounds, with particular reference to those which are necessary in nutrition.

TOTAL-MOISTURE DETERMINATIONS.

The determination of the current-moisture content of the soil at a given point is an exceedingly simple matter, and a vast amount of such work has been done in connection with agricultural investigations and greenhouse experiments; in fact, so much has been done that citations are useless.

On the other hand, repeated determinations at a given point to show changes, minima, etc., immediately introduce complications. When a sample has been taken from the ground, it is very difficult to fill the space with the same kind of soil as before, and even if this were accomplished the new soil would not soon be in a normal moisture condition. The next sample must, therefore, almost certainly be taken a short distance away, and almost invariably this introduces a change in composition, such that equal moisture contents in two successive samples may not have the same plant value. Usually in agricultural soils or well-mixed potting soils, these variations may be ignored. Very often in forest soils, however, the changes in composition are very abrupt; in fact there is often no such thing as uniformity of soil texture, even in a practical sense. The sampling of forest soils, moreover, is often difficult owing to the presence of rocks which make it impossible to obtain a sample at the desired spot, at least with borers of any description. These mechanical difficulties may usually be overcome by the use of pick and shovel, and in careful surveys of the root zones of individual trees or groups such methods will undoubtedly have to be resorted to.

In practice, it is usually impossible to examine a large number of soil points with sufficient frequency to show even approximately the changes in soil moisture. It is necessary to select, more or less arbitrarily, points which seem to represent the average of conditions in the plant formation or forest type under study, and to confine the effort to showing as accurately as possible all the conditions which occur at this point.

SOIL-WELLS FOR REPRESENTATIVE POINTS.

In view of what has been said, it appears necessary to make provision for establishing some standard conditions under which soil samples shall be taken at permanent stations. The ideal method would undoubtedly be to show the moisture content of a single sample of soil from time to time, and it has been suggested that this might be accomplished by the periodic weighing of a standard soil sample contained in a porous cup which would be permanently located at the soil point. This plan involves a number of technical difficulties, and is, moreover, wholly untried. The nearest practical approach to the method of a single sample would seem to be in the plan of

soil wells, which has been thoroughly tried at the Fremont Experiment Station and elsewhere.

At each station where soil moisture is to be determined periodically, a well 18 to 24 inches in diameter and 4 or more feet deep may be dug. At the nearest available point a soil quarry is established for each station or group of stations having similar soils. From this quarry is taken soil containing only a moderate amount of humus, and which should be sifted through 4-mesh screen. At the outset sufficient sifted soil is obtained to fill the well and to furnish 1 or 2 cubic feet of reserve, the whole being thoroughly mixed. The sifted soil should be firmly tamped into the well. It will be better if the well may be allowed to stand a year before being used, the soil becoming settled by water action and being to some extent penetrated by roots.

In order to maintain uniform conditions at the surface, each soil well should be kept free of litter by means of a frame of 1 by 4 inch boards, 18 or 24 inches square, which may be slightly sunk in the soil. Over this is placed a slightly larger frame covered with hardware cloth. It is evident that this frame will interfere with surface erosion. The surface of the soil in the well should at all times be kept flush with the surface of the ground around, so that the amount of water available for absorption is not appreciably greater or smaller than elsewhere.

At the time of digging any soil well, samples of the native soil at 1, 2, and 3 feet from the surface and other depths at which moisture is to be determined, as well as one of the prepared soil for the well, should be obtained for testing. Each sample should comprise about 30 pounds and should be air-dried, unless it is to be used immediately.

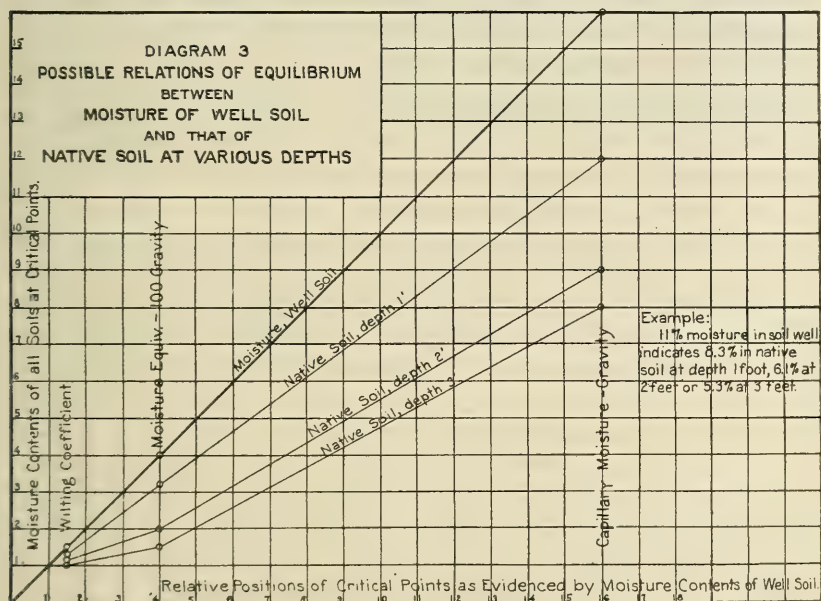
Each soil quarry should be permanently designated at the time of its first use, and a record may be made of the quality and location of material taken therefrom, so that in the future fresh supplies for the well may be obtained, with a little trial, very nearly like the original.

As such soil wells are used year after year, it will be noted that the finer material is to some extent concentrated in the lower layers, especially if the soil of the well is decidedly sandy and loose. This will not be found so important a change if the soil is compact, or contains considerable humus.

The question naturally arises, how will the moisture in one of these wells compare with the moisture of the native and undisturbed soil on either side? For the reason that the soil of the well is quite certain to be finer than the native forest soil, it is evident that the well soil will always contain a higher percentage of moisture. Furthermore, without going into all the details, this question is answered unequivocally by saying that the moisture content, as determined

for the well soil, can never be considered as an exact measure of the moisture outside. The well samples will be principally useful in showing changes, and without doubt should occasionally be compared with native samples taken near by. It is believed, however, that for practical purposes a certain constant relation between the two soils may be assumed. So far, because of the great difficulty of actual contact tests between two soils, the moisture ratio at equilibrium must be established on theoretical considerations.

From what is known of capillary movement in soils (116) it would seem that, when the moisture content of two soils is near the saturation point, they will be in equilibrium at moisture values measurable by the amount which either soil can hold against the force of gravity.



Similarly, at much lower moisture contents, the amounts which the two soils hold against a force one hundred or one thousand times as great as gravity, would appear to establish a basis for equilibrium. But, in view of the fact that at a low-moisture content actual capillary movement becomes negligible while transfer from one to the other by the vapor-transfer method can be readily accomplished, it seems more logical that we should consider an equilibrium existing which would mean equal osmotic pressures in the two soils. These points can be determined for each soil by freezing-point depressions or by assuming equal osmotic pressures at the wilting coefficients.

Diagram 3 shows a method for working out a scale of relations for the soil of any well and soil from three depths, obtained when the well was dug. The curve for the well soil is a straight line whose

ordinates and abscissæ are equal. It need not be drawn at all, except for illustrative purposes. For each of the native soils three or more points may be plotted. The capillarity point has as its ordinate the actual capillarity of this soil; but the abscissa has the value of the capillarity for the well soil, similarly, for the moisture equivalent at 100 gravity (which is still a capillarity measure) and the wilting coefficient, or any other point at which osmotic pressure of the several soils would be in equilibrium. (See also diagrams 8, 9, and 10 and discussion, p. 116.)

These curves may then be used to transpose moisture values for the soil well directly into moisture values for the native soil, realizing the probability which has been mentioned that at any moment the well and native soil may be far from a state of actual equilibrium.

TECHNIQUE OF PERIODIC SAMPLING.

The field work of soil sampling is essentially the same where soil wells are used as where it is feasible to sample the native soil. Soil samples should be taken at permanent stations at least weekly during the open season. Definite depths of 1, 2, and 3 feet, and more if necessary, will recommend themselves in preference to long cores, which show less definitely the location of the moisture. The 1-foot sample may be obtained by a core extending from 10 to 14 inches; the 2-foot, at 22 to 26 inches; and the 3-foot, at 34 to 38 inches. If intermediate values are desired, they may be obtained by interpolation.

Each sample as obtained should be placed in a soil can, the number of which may immediately be entered on a convenient field form,¹⁰ together with the number of the station and the depth. There is an infinite variety of soil cans, but perhaps the most generally serviceable form is a rather heavy, stamped aluminum, screw-top can, about $2\frac{1}{4}$ inches in diameter and $2\frac{1}{2}$ inches high.

Soil cans containing moist soil must be shielded from the sun and from excessive heat, and should be weighed at the earliest opportunity, the weight being ordinarily determined to the nearest centigram. (Fig. 2.)

Soil samples of any ordinary texture, and of weight not exceeding 100 grams, should be dried for at least eight hours in an oven having the temperature of boiling water. Unusually moist samples, or those of very fine texture, should be given a longer period. Drying for 24 hours is not too long to make good results certain. Especial care must be used with humus soils of low conductivity. Only trial weighing will show when a sample is as dry as possible for the conditions of the oven.

¹⁰ Forest Service Form 486, fitting notebook cover 874-C.

After drying, each soil can should be immediately covered and weighed.

The moisture percentage should be determined on the basis of dry weight of soil, by deducting the can weight from the dry weight, deducting the dry weight from the wet weight, and dividing the



FIG. 2.—Ordinary soil cans, for collection of moisture samples, with covers removed.
Size $2\frac{1}{4}$ by $2\frac{1}{2}$ inches.

second remainder by the first remainder. Moisture percentages are usually worked out to one or two decimal places.

Soil cans in continuous use should be weighed at least twice each season, preferably at the beginning and middle of their periods of use. Aluminum cans, while satisfactory in most respects, wear appreciably in a few months.

[United States Department of Agriculture, Forset Service.]

PHYSICAL SURVEY—SOIL MOISTURE.

Type _____; Station No. _____; ^{cover} _____; ^{open} _____; mark out one; for the month of _____, 19____.

[illegible]

* COMPUTATIONS OF AVAILABILITY OF SOIL MOISTURE, ETC., FROM DATA GIVEN ABOVE.

[illegible]

* Data on which computations are based.

*** Explanation of symbols used in captions.

Prepared by

The figures resulting from the above computations for the moisture of the soil in soil wells may be tabulated on the "Soil Moisture" form in the columns headed "Sample, T1." The ratio which has been determined between the moisture of the soil in the well and that of the native soil at same depth, and the computed moisture of the surrounding soil, or the moisture figure read directly from curves, may also be entered for each date. If the native soil moisture is directly determined by sampling, only the third column under each depth will be used. Space is also provided on the "Soil Moisture" form for any computations which it is desired to make, either currently or after obtaining the monthly means; such as, for example, the percentage of available moisture, the availability, or the various percentages on a volume basis. Appropriate headings may be supplied.

DETERMINATION OF NONAVAILABLE MOISTURE.

The method of soil wells does not attempt to standardize soils for different localities, which could only be done thoroughly by using soil from one source in all soil wells. Nor is it desirable that soils of different localities should be compared on the same physical basis, since this physical basis of itself determines quite largely the mean water content of the soil and its attraction for a given species. It is, however, necessary before different sites and localities may be satisfactorily compared as to their soil moisture that it should be known, at least approximately, at what points they become physiologically dry, either for plants in general or for plants of a given species. Briggs and Shantz (114), it is true, after an exhaustive study of this subject which has cleared the way for many other investigations, summarize in part as follows:

The results of this investigation have led us to conclude that the differences exhibited by plants in this respect are much less than have heretofore been supposed, and are so small as to be of little practical utility from the standpoint of drought resistance. As compared with the great range in the wilting coefficient due to soil texture, the small differences arising from the use of different species of plants in determining the wilting coefficient become almost insignificant.

Expressing this difference numerically, it is said:

Taking 100 to represent the average wilting coefficient, the different species tested (except *Colocasia* and *Isoetes*) give an extreme range from 92 for Japan rice to 106 for a variety of corn.

From these experiments and conclusions the impression has grown up that all plants are capable of extracting the moisture of the soil to essentially the same basic point. Shantz may be quoted as saying that there was no intent to convey this impression, and experiments to be described later will show that as between tree species

adapted to radically different habitats, there may be, at least under certain conditions of wilting, radical differences in the coefficients. Another important phase of the matter is that certain soils may have a peculiar reaction on one species and not on others; as, for example, a highly acid or strongly limy soil. It is therefore the part of wisdom to test the nonavailable moisture of any soil by the use of at least the predominating or type species found on the soil, and of as many other species as possible.

DIRECT DETERMINATION OF THE WILTING COEFFICIENT.

The writers cited above have given such thorough consideration to this and the succeeding subjects that a complete discussion here appears almost useless. The treatment of forest soils and forest species, however, has brought out a number of new problems, so that it is almost impossible to overlook any phase of the question in this discussion. Constant comparison will be made with the treatment found desirable for field crops and related plants.

It is well to bear in mind from the outset the point brought out by Briggs and Shantz that the wilting coefficient represents merely the moisture point at which wilting first occurs to such an extent that the plant does not recover if placed in a saturated atmosphere. The plant may actually draw considerable water from the soil after this, and might be theoretically conceived to pass moisture to the atmosphere until the soil and atmosphere were in vapor-pressure equilibrium. The wilting coefficient is, however, the practical expression for nonavailable moisture.

The fact must also be strongly emphasized that the point at which wilting occurs must depend in a very large measure on the rate at which the plant is transpiring; or, in other words, on atmospheric conditions and sunlight. Therefore, as the soils approach dryness, the conditions should be maintained at a fairly definite standard. It will usually be feasible to prevent the occurrence of temperatures in excess of 70° F., as well as sudden changes in temperature, and to exclude direct sunlight. It would also be desirable to control atmospheric moisture, though this is a very difficult thing to do in ordinary rooms.

In the tests with seedlings of coniferous trees it has been found exceedingly difficult to determine when permanent wilting occurs. There is no doubt that seedlings of this kind have developed a power of resistance, or recovery, far in excess of that of most plants. This probably consists in an extremely low rate of transpiration when the moisture becomes deficient; but the difficulty of observation may be mainly ascribed to the fact that the stems, and to a lesser extent the leaves, become stiff and woody at a very early age, so that shriveling rather than collapse is the phenomenon that evidences

lack of water in the aerial portions. This is particularly true of yellow pine and Douglas fir seedlings, at the age of six weeks or more, while lodgepole pine does not harden until much later.

For these reasons wilting can rarely be recorded in a large number of seedlings simultaneously, and it is therefore desirable that the moisture content should be recorded as each seedling wilts, an algebraic mean content being computed when the process is complete.

While Briggs and Shantz found it desirable to grow the seedlings in small glass pots (these seem to have had about the dimensions of drinking glasses), the heterogeneous character of nearly all forest soils necessitates the treatment of samples large enough to include a normal proportion of rock fragments. If these are very large they may be broken down to maximum dimensions of about 2 inches without appreciable alteration of their relations to moisture, but



FIG. 3.—Echard pans, 7 by 3 inches, containing seedlings.

that is all that can be done. These rocks can not be eliminated altogether, as it is found that the more permeable of them may hold 1 to 2 per cent of nonavailable moisture. They are distinctly a part of the soil and it is their presence which, in a large measure, makes the soil capable of supporting forest growth.

A pan (fig. 3) which meets these requirements is made of 20-gauge or 24-gauge galvanized iron, 3 inches deep and 7 inches in diameter. Half a dozen small perforations in the flat bottom permit drainage while the seedlings are being started, and aeration after the surface of the soil has been sealed over. When filled to a depth of $2\frac{1}{2}$ inches, such pans hold 3 to 6 pounds of soil.

To avoid any chemical change in the soil, but more particularly to keep it receptive toward moisture, the dry weight of soil placed in the pan is determined rather by moisture samples secured as the pan is being filled than by drying the whole mass. The latter, moreover, is a slow process, especially with soils of low conductivity.

However, no bad effects whatever have been noted from drying fairly sandy soils at the standard temperature.

After obtaining the air-dry weight of the pan and soil, an amount is removed from the pan sufficient to form a layer one-fourth of an inch deep. The coarser material is excluded from this lot, which is to form a covering for the seeds. With this taken out, the remaining soil is leveled down with a spoon, the seeds are sown on this smooth surface, and the covering soil is replaced.

The number of seeds to be sown should be gauged according to known viability, so as to produce about 100 seedlings in a pan of this size. The weight of the seeds is obtained before sowing, and this weight is considered throughout as an addition to the tare. The further assumption is made that the weight of the seedlings will not at any time appreciably exceed the weight of the seeds.

Having calculated the net dry weight of the soil from the moisture content of the dried sample, the moisture content of the soil at any stage in development or wilting of the plants is calculated, after a weighing of the pan, by the equation:

$$\text{Moisture percentage equals } 100 \times \frac{W - (\text{Pan, seed, soil, and paraffin})}{\text{Soil}}.$$

The pans are placed in a greenhouse where they may have the necessary light and warmth to induce prompt germination, and for the sake of uniform development and conditions affecting wilting, are preferably kept on a revolving table.

The soils are watered exclusively with distilled water, both to avoid the introduction of spores and the addition of salts, which, in the absence of drainage, might appreciably increase the wilting coefficient. Nothing suggestive of a toxic effect from this distilled water has been noted. It is desirable to aerate the water as much as possible before applying. Under ordinary atmospheric conditions, the pans will require 50 to 60 cubic centimeters per day to maintain moisture favorable for germination.

In working with deeper mineral soils, damping off of seedlings is rarely noted, but surface soils from the forest often contain the damping-off fungi. In fact, this is so common that many observations which ascribed the death of seedlings in the forest to unfavorable physical conditions may be questioned. Certain it is that damping off in the wilting pans may cause the greatest confusion, if they do not actually vitiate the tests. Soils suspected of containing these organisms should therefore be treated, several days before the seed is sown, with a solution of formaldehyde, as suggested by Hartley (124) for nursery beds. This should be used at the rate of about one-eighth of a fluid ounce per pan, dissolved in sufficient clean water to reach all soil in the pan. Opportunity should afterwards

be given for the formaldehyde to evaporate entirely. This will doubtless occur before the soil is perfectly dry.

When germination is fairly complete, the seedlings well established so as to reach all parts of the soil, and the tendency to succumb to damping off, if any, outgrown, the surfaces of the pans are sealed over by pouring on the top of the soil, previously leveled, about 50 grams of a melted mixture of paraffin and petrolatum (veterinary vaseline is one of the least expensive forms) in the proportion of 2:1. This congeals at 40° C. and may be applied at 50° C. without any injury to the stems of the seedlings. Not infrequently, if the wilting process requires many days, the seal will draw away from the edges of the pan, but this is easily rectified by the use of a blunt, smooth stick. At any rate, it is not essential absolutely to prevent direct evaporation from the soil, though a more even distribution of moisture may be expected if such loss is kept at a minimum.

The weight of paraffin added is determined by weighing the beaker from which it is poured before and after each application. This makes a further addition to the tare. The soil should be fairly moist when the paraffin is applied, so that the latter will not penetrate.

With coniferous seedlings, provided a good stand has been secured, the withdrawal of moisture and the sealing of the pans may usually be undertaken at four to six weeks after sowing; though in the case of spruce and perhaps other species which root rather slowly a slightly longer period may be desirable. As has been pointed out, the difficulty of detecting wilting increases as the seedlings become older and more completely lignified. It is also unmistakably true that the older the seedling the more difficult it is to kill. This is probably due in part to greater resistance to drying out and in part to deeper or more extensive rooting, which would be an advantage if the moisture at, say, the bottom of the pan, were not being drawn on as freely as that near the surface. However, observations on the wilting of seedlings under direct insolation point unmistakably to resistance increasing with age. When the surface of the soil becomes extremely warm, even if there is an abundance of moisture within reach of the roots, wilting is likely to be evidenced by collapse of the stem at the ground line. The phenomenon is almost identical when the surface of the soil becomes dry in advance of the deeper soil. The seedling is undoubtedly vulnerable to water loss and critical injury in the lower part of the stem. Under such conditions it is noted that the younger seedlings usually succumb first, and those which survive one exposure are killed by a repetition which is still more severe.

It is evident, therefore, that age of seedlings will have an important influence on the results, though this will not be so important if

the test is conducted in such manner as to keep the moisture uniform throughout the soil, and hence uniform for the deepest and shallowest-rooted seedlings.

It is also self-evident that specific differences may be brought out by one set of conditions, which would not be apparent in another set, particularly conditions which make the requirement for moisture great or small. If transpiration is very rapid, seedlings of a shallow-rooted species may be unable to meet this demand, while deeper-rooted seedlings in the same pan may pull through, because their supply at this stage is somewhat more readily obtained. For an actual test of drought resistance, therefore, it is fundamentally necessary that the transpiration and soil-drying process should be slow enough to permit equalization of the opportunities before the critical test comes. Hence the standard conditions of exposure which have already been suggested.

The method of recording the death of each seedling in a lot of 100, together with the pan weight and calculated moisture accompanying such death, has a distinct advantage over the method which permits only one determination of the moisture content when all of the seedlings, or a majority of them, have succumbed. It gives an indication of the possible variation between individuals of the same species, and a measure of the probable experimental error due both to this variation and to uneven distribution of moisture in the pan, which is not wholly avoidable. What it really amounts to is practically 100 separate tests on 100 sections of soil. If, on the one hand, the first losses occur in sections of the soil which have unavoidably become drier than the average, on the other hand, the last survivors are undoubtedly in areas which are at the opposite extreme. These variations should be largely compensated by taking the algebraic mean of all the moisture determinations, a figure in which a great deal of confidence can be placed.

INDIRECT METHODS FOR WILTING COEFFICIENTS.

Inasmuch as the direct determination of the wilting coefficient is a process which is likely to require several weeks, at the best is liable to rather large experimental errors, and is also, without question, influenced by the kind of plant used, various methods have been developed by which the affinity of the soil for water may be determined; and the amount of water held by it under certain empiric conditions of the test may be related to the amount which would be held against the pull of plants.

In addition to furnishing a ready, if only approximate, index to the soil conditions which may be encountered in the field, and especially an index to the danger of early drought, it seems that the use of indirect methods, employing definite physical forces for the crea-

tion of a certain condition of soil moisture, has a scientific value which fully justifies an elaborate description of them. For example, such methods permit us to compare the drought resistance of any number of species in any number of soils through any period, provided only that the experimental conditions are reproducible. We can determine this relative drought resistance, as between two or three species, by wilting them simultaneously in the same soil mass, and gradually, by one comparison and another, include all of our species and all of our soils. Even this method, however, is not free from the necessity for uniform conditions in the successive tests. It is therefore best that each wilting coefficient, while being determined under some arbitrary and standard set of conditions, should be related to some other measure of the soils' water-holding capacity which, under reproducible test conditions, always means just one thing. In this way an enormous number of comparisons may be made between the wilting coefficients for different soils and different species. Such physical determinations may also lead to a critical examination of wilting coefficients and to the most desirable standard methods for their determination.

Of the various indirect methods which have been devised may be mentioned:

1. The determination of the antiosmotic pressure of the soil, corresponding to the maximum osmotic pressure which the species under consideration is known to tolerate without fatal results. This method is obviously not so useful as the others, since it presupposes some knowledge of the plants which may not be available. It must necessarily consist of a number of determinations on the same kind of soil, at different moisture contents, until the moisture condition is found at which the freezing point becomes "submerged;" that is, becomes indeterminate. Obviously, this leads to the region in which the freezing-point determinations are least precise. While not abandoned, this method will be laid aside to be discussed more fully, and in its most useful aspects, in connection with the coefficient of availability.

2. The capillary moisture determination, in which the soil is allowed to demonstrate its ability to hold water against the force of gravity.

3. The moisture-equivalent determination, in which the moisture in the soil is subjected to any definite force, dependent on its own mass. This may be a force one hundred or one thousand times as great as gravity created by the centrifugal method.

4. The hygroscopic coefficient determination, in which the affinity of the soil for moisture is determined by exposing it to an atmosphere of saturated vapor.

The *capillary moisture*, or "capillarity," the terms being used interchangeably, in this discussion, refers to the quantity of water

that may be held by the soil against the force of gravity. This amount decreases as the height of the column of soil increases, and may also be considerably influenced by the packing of the soil. Since it is almost impossible to treat any soil in the same state of compactness in which it is found in the field, or to establish a standard condition for soils in vessels, this measure of the water-holding power of a soil is not likely to have precise value. The greatest theoretical objection to it is, that the force tending to remove the water from the soil is of an entirely different magnitude from that at work as the plant makes its final struggle for water, and that the effect produced by the one force can not serve as a measure of the effect which might be produced by the other. There seems also to be an impression that salts in the soil water operate to raise the wilting coefficient, while decreasing the capillary moisture by lowering the surface tension of the liquid. Such an impression arises from the well-known effect of foreign substances on the surface of a liquid. It has been pointed out by Free (121) that salts in solution actually increase the surface tension of the liquid, and this is entirely in keeping with the known properties of solutions. While the presence of solutes may have the effect of weakening the affinity of one water molecule for another, this is fully counterbalanced, in its relation to capillarity, by the greater density of each group of molecules of which the solute forms a nucleus, and the consequent greater affinity between such groups and the solid surface. This affinity is known by the name of "capillary attraction." Furthermore, even while admitting that in either the capillary moisture test or the moisture equivalent test some of the solutes may be lost with the water which is drained out of the soil, considerable satisfaction is gained from the idea previously set forth that, at the wilting point of soils, these solutes may be absorbed by the colloids.

It is believed that Hilgard (125) was the first to employ the principle of capillarity for comparing soils. He used a sieve cylinder only 1 centimeter high, which, after a layer of filter paper was placed in the bottom, was filled level with the soil. This was immersed to a depth of 1 millimeter in distilled water, allowed to stand for an hour, and then weighed. The amount of water absorbed, of course, was dependent on the ability of the soil to lift it, a maximum distance of 9 millimeters.

Briggs and Shantz (114) compared this measure of absorbing capacity with the directly determined wilting coefficients of 15 soils whose wilting coefficients ranged from 0.9 to 16.7 per cent. From these comparisons it is evident that a soil which is able to withhold almost no moisture from plants has a fairly high capillarity, but that the latter does not increase in so great a proportion as the wilting coefficient with more retentive soils. Thus it was neces-

sary to subtract 21 from the percentage of capillary moisture to obtain a quantity having a fairly constant ratio to the wilting coefficient.

This is given by $\frac{\text{Capillarity}-21}{\text{Wilting Coeff.}}=2.90\pm0.06$, or ± 2.01 per cent.

The probable error of a single determination by this means was found to be 8.3 per cent of the wilting coefficient.

In the treatment of forest soils (105), at the Fremont Experiment Station, has found it necessary to use much larger cans than those employed by Hilgard, and has also reversed the process, so that the result is rather a measure of the ability of the soil to hold the water of saturation than to lift water from below. A galvanized can $5\frac{1}{2}$ inches deep and 4 inches in diameter, is filled to a depth of 5 inches with air-dried soil, which is jarred and tamped until no appreciable settling occurs. This can is perforated in the bottom and a filter paper is used to keep the soil from sifting out. The can is immersed to its full depth in water, but no water is allowed to flow on the top of the soil. As the water rises from the bottom by its own pressure, the air is pushed out, so that few, if any, air spaces are left. The samples are allowed to soak at least 24 hours to insure complete absorption by the larger, permeable rock fragments.

The weight attained at the end of this period, or a longer period if it appears necessary, is an index to the saturation capacity.

The cans are now placed on a drain board, covered, and allowed to stand for 48 hours. In rehandling the cans care must be used to avoid jarring, as some of the water is held in a very delicate balance. The amount of water held at this time is a measure of the capillary moisture. In the vast majority of soils that have been treated, the capillary moisture is about 90 per cent of the saturation capacity. Clay does not affect this ratio appreciably, but humus increases it.

The same cans are now used for the centrifugal test or moisture equivalent determination, which will shortly be described. After this they are oven-dried, to give the basis for dry-weight calculations. The apparent density is also computed from the weight and volume after this treatment.

In Table 2, there is presented a comparison of the capillary moistures and wilting coefficients of 10 soils of one general type (granitic) from an Engelmann spruce forest, but varying widely in state of decomposition, clay content, and humus content. Each soil represents a sample extending from the surface to a depth of 1 foot. The wilting coefficients for Douglas fir and Engelmann spruce were most carefully determined, the only objection that might be brought against the treatment being that the seedlings were given more direct

light than now seems desirable, although not enough to develop excessive temperatures. In contrast, there are also presented the results of nine tests on coarse granitic gravels, from depths of 1 to 3 feet, containing minimum amounts of humus and clay. The wilting coefficients were determined in the same manner as the other group, and at almost the same time.

TABLE 2.—*Capillary moisture, moisture equivalent, and wilting coefficient of 19 soils. (Wilting coefficients determined synchronously.)*

Sample No.	Capillary moisture (G).	Moisture equivalent (100-G).	Mean wilting coefficient (spruce and fir). ¹	Humus by ignition.	Clay.	Water ² soluble matter.	Ratio mean wilting coefficient.		Final ³ wilting coefficient.	Ratio final wilting coefficient.	
							To capillarity.	To moisture equivalent.		To capillarity.	To moisture equivalent.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Parts per million.</i>			<i>Per cent.</i>		
539	17.07	11.68	3.17	3.29	4.5	305	0.186	0.271	2.56	0.150	0.219
555	20.29	11.72	3.00	3.52	0.4	275	.148	.256	2.52	.124	.215
554	24.06	14.45	3.90	3.00	2.2	465	.162	.270	3.30	.137	.228
547	29.34	20.32	6.01	6.56	6.7	270	.205	.295	5.26	.179	.259
545	33.77	22.02	6.02	7.09	3.6	845	.178	.273	5.18	.153	.235
549	36.16	19.95	7.04	6.04	4.2	555	.195	.353	6.10	.169	.306
544	41.56	26.30	8.68	11.64	3.4	1,030	.209	.330	7.83	.188	.298
526	49.92	29.84	8.60	9.75	3.2	530	.172	.288	6.95	.139	.233
546	60.00	42.72	20.46	21.10	2.6	200	.341	.479	11.17	.186	.262
538	89.05	73.50	21.71	27.00	2.7	1,250	.244	.295	13.89	.156	.189
Group averages, granitic loams							.204	.311	.....	.158	.244
292	11.02	5.04	2.73	1.02	1.5	700	.248	.542	1.79	.162	.355
37	11.45	3.53	2.00	1.33	0.2	500	.174	.567	1.18	.103	.334
235	12.00	5.06	3.09	2.09	3.1	800	.257	.611	2.25	.188	.445
36	12.95	4.35	2.47	1.74	2.7	500	.191	.568	1.64	.127	.377
293	12.96	5.62	2.93	1.79	1.5	200	.226	.521	2.06	.159	.367
82	13.18	4.86	2.27	1.85	1.9	600	.172	.467	1.85	.140	.381
83	13.61	5.19	2.76	1.76	2.5	500	.203	.532	1.76	.129	.339
85	15.30	5.57	2.54	1.92	2.1	800	.166	.456	1.62	.106	.291
84	15.65	5.03	2.54	1.31	3.7	800	.162	.506	1.62	.104	.322
Group averages, granitic gravels							.200	.530	.....	.135	.357
Grand averages							.202	.415	.....	.147	.298
Mean variation of single values							.0333	.1137	.....	.0228	.0607
Percentage of mean variation							16.5	35.9	.....	15.5	20.4
Probable error in average							.0066	.0230	.....	.0045	.0121

¹ In these tests spruce and fir gave almost the same figures, on the average.

² 200 grams soil leached on filter, with 1 liter water, through 24-hour period. For the gravel group results are approximations, on account of lack of sensitive scale.

³ Average of the moistures existing for last tree of each species.

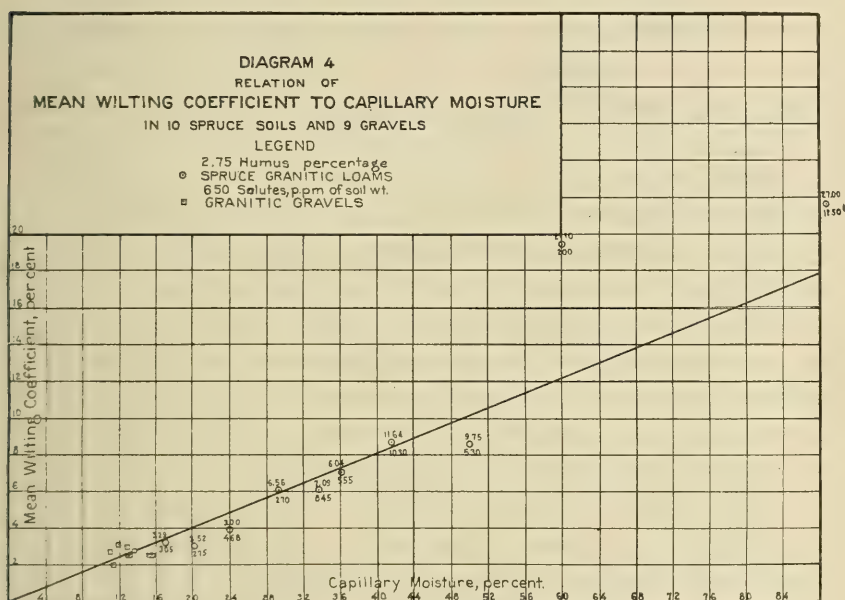
To avoid duplication of tables later there are also inserted here the moisture equivalents of the same soils.

The comparison of capillary moisture and wilting coefficients given in Table 2 brings out the following facts:

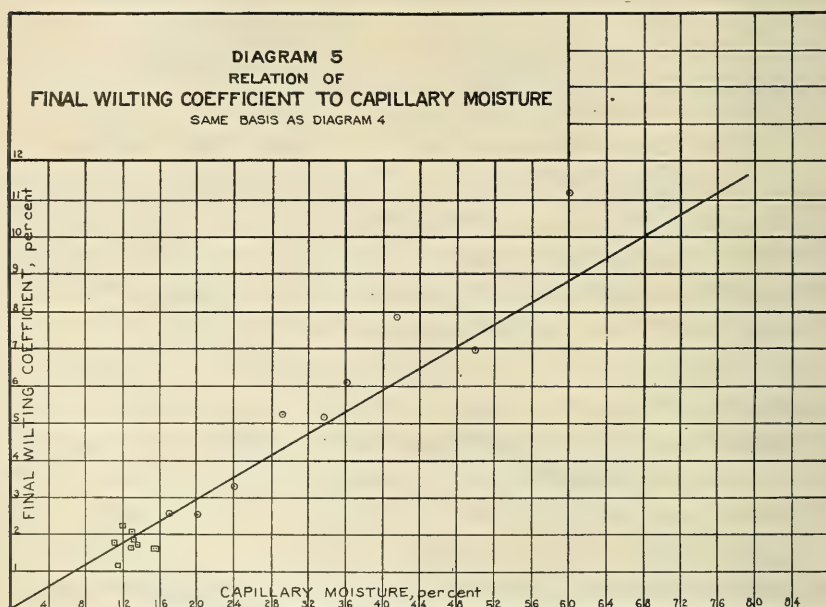
1. An examination of the column headed "Ratio of mean wilting coefficient to capillarity" shows that there is considerable variation in the individual results. In the first group the two results which are appreciably higher than the average are those for samples of the highest capillarity, resulting from unusual quantities of humus.

2. The group averages for the loamy spruce soils and the granitic gravels are essentially the same. It therefore seems entirely legitimate to consider both groups together and, as shown in diagram 4, to express the relation of wilting coefficient to capillarity by a straight line. The nineteen cases show an average variation of 0.0333 from the mean ratio of 0.202, or 16.5 per cent variation.

3. Both from its mean value and from the fact that the graph which expresses this relationship passes through the main axis of the system of coordinates it is evident that the capillary moisture as it has been measured by the method described above is an entirely



5. It is to be noted that the percentage of variation of individual cases is slightly less when the final (diagram 5) rather than the mean wilting coefficient of each soil is taken. On the other hand, there is considerably more spread between the two groups on this basis. It is believed that the slightly poorer showing made by using the mean wilting coefficient is due to the fact that losses caused primarily by fungi were not entirely eliminated from the calculations. With care in this respect, the mean value for all the seedlings is undoubtedly the more dependable and also more expressive. It should be noted in this connection that in a group of 100 seedlings the weakest usually



give a wilting coefficient twice as high as that indicated by the final wilting, and not infrequently three times as high.

6. The comparison of wilting coefficients with moisture equivalents shows a wide gap between the two groups. The value of the moisture equivalent data will be discussed later.

7. While these results, all obtained at practically the same time and in soils which showed no great chemical activity, indicate a useful parallelism between wilting coefficient and capillary moisture, it should be pointed out that the wilting coefficient may occasionally go out of bounds as the result of acidity or alkalinity, so that any of the physical tests on soils, taken alone, are quite worthless. It should not be surprising to obtain wilting coefficients twice as great, relative to capillarity, as those indicated above, especially with the pines.

It is desired to present another set of data obtained by Bates (105) to illustrate the need of establishing the wilting coefficient for the particular species in which one may be interested and, therefore, of establishing a specific relationship between the wilting coefficients and the capillary moistures of the same soils. This presentation also assists in showing, what has already been mentioned, that a measure of the capillarity or other moisture relation of the soil has an indirect value in permitting comparisons of the species under a variety of conditions.

The tests as represented in Table 3 were performed on five distinct kinds of soil, varying as to origin (hence, chemically) and also considerably as to composition and water-holding capacity. With the exception of the prairie soil, which contained only 1 per cent of coarse sand and no gravel at all, these soils were prepared by passing through a sieve with quarter-inch meshes.

The wilting coefficient determinations, moreover, were made without the use of paraffin. As the test was designed particularly to compare the four species which were grown in each soil, and it had become apparent that the rooting habit of each had a good deal of bearing on the stage in soil drying at which it succumbed, the effort was made to keep the upper layer of the soil well supplied with moisture by daily watering. As a result, the common drying of the steam just at the ground line was not appreciably in evidence and, indeed, so general was the drying that the determination of the end point was exceedingly difficult. It was based almost wholly on the flaccidity of the leaves. Whether because of this protection afforded the stems by surface watering, or because of the comparative shade in which the end points were approached, it is noteworthy that the ratios of wilting coefficients to capillarities are much lower, except for the heaviest clay, than in the results obtained under different conditions and already described.

Another noteworthy feature of this test is that the seedlings were produced in each soil with the moisture brought daily to the moisture equivalent, so that the availability was, as nearly as could then be calculated, the same in all cases. When drying began, each soil was brought by easy stages to two-thirds of the moisture equivalent, and finally to one-third. The seedlings attained an age about 6 months before the test was completed.

TABLE 3.—*Wilting coefficients of four species in five types of soil.*

Sample No. and description.	Capillary moisture.	Moisture equivalent 100-G.	Mean wilting coefficient.			
			Yellow pine.	Lodgepole.	Douglas fir.	English spruce.
590. Sifted granite gravel with loam.....	<i>Per cent.</i> 26.58	<i>Per cent.</i> 10.55	<i>Per cent.</i> 2.50	<i>Per cent.</i> 2.79	<i>Per cent.</i> 2.60	<i>Per cent.</i> 2.72
604. Composite limestone.....	31.85	22.00	3.82	4.74	4.06	4.03
602. Composite sandstone.....	35.34	21.77	5.01	6.30	5.08	4.87
601. Prairie soil from shale.....	37.77	28.79	8.65	9.65	8.52	8.76
603. Composite lava.....	43.16	27.80	5.56	7.48	5.44	5.31
Averages.....			5.11	6.19	5.14	5.14

Sample No. and description.	Ratio wilting coefficient to capillary moisture.					Fine material.	
	Yellow pine.	Lodgepole.	Douglas fir.	Spruce.	All.	Silt.	Clay.
590. Sifted granite gravel with loam.....	0.094	0.105	0.098	0.102	0.100	<i>Per cent.</i> 13.5	<i>Per cent.</i> 5.4
604. Composite limestone.....	.120	.149	.128	.127	.131	45.8	11.4
602. Composite sandstone.....	.142	.178	.144	.138	.150	41.8	11.0
601. Prairie soil from shale.....	.229	.256	.226	.232	.236	53.3	17.2
603. Composite lava.....	.129	.174	.126	.123	.138	51.9	11.1
Averages.....	.1428	.1724	.1444	.1444	.151	-----	-----
Mean variations of single determinations.....	.0346	.0364	.0324	.0348	.0389	-----	-----
Percentage of mean variations.....	24.2	21.1	22.4	24.1	25.8	-----	-----

Sample No. and description.	Ratio of wilting coefficient to moisture equivalent.			
	Yellow pine.	Lodgepole.	Douglas fir.	Spruce.
590. Sifted granite gravel with loam.....	0.237	0.265	0.247	0.258
604. Composite limestone.....	.174	.215	.185	.183
602. Composite sandstone.....	.230	.290	.233	.224
601. Prairie soil from shale.....	.301	.335	.296	.305
603. Composite lava.....	.200	.269	.196	.191
Averages.....	.2304	.2748	.2314	.2322
Mean variation of single determinations.....	.0328	.0302	.0328	.0394
Percentage of mean variations.....	14.2	11.0	14.2	17.0

The wilting coefficient tests given in Table 3 bring out the following facts:

1. The line showing the percentage of the mean variations indicates that the four species taken together and comprising 20 cases have a larger variation from an established mean ratio than any of the individual species. Lodgepole pine shows the highest relative wilting coefficient, and, since the other three species gave almost identical results, it follows that a ratio established by the promiscuous use of species would be most largely in error when applied to calculations for lodgepole.

2. The relatively high wilting coefficient for lodgepole pine has been thoroughly established by numbers of other tests, which, how-

ever, are not given here because the results do not coordinate closely with this set.

3. It is noteworthy that the coefficients for all species in the limestone soil are relatively low, while the really high values are given by the heaviest clay. The latter fact, like the result in a strongly humous soil, is believed to be due to nonconductivity of the clay.

4. In this case the correlation between wilting coefficients and moisture equivalent is a great deal better than the correlation with capillary moisture. In view of what has been said regarding the level of moisture maintained in each pan, it seems pointed to suggest that the wilting coefficient may depend in some measure on the degree of moisture to which the seedlings have become accustomed. It is only logical to suppose that, if abundant moisture tends to stimulate growth, the seedling may, when drought occurs, be relatively deficient in the carbohydrates which assist in osmosis.

The moisture equivalent is a term devised by Briggs and McLane (113) to define the amount of water held by a soil against a definite external force. In the original experiments of these authors the force employed was a centrifugal force exerting a pull 3,000 times as great as the force of gravity. The small samples of soil were placed in finely perforated cans, which in turn were placed against the inside wall of a heavy cylinder. The latter was caused to rotate rapidly by direct connection with a motor.

In this early work the writers seem to have made no attempt to correlate the moisture equivalents with wilting coefficients. There was, however, a fairly successful formula devised by which the holding power of the soil was related to the constitution thereof, as shown by mechanical analyses. This, it is believed, has been found of little use.

It remained for Briggs and Shantz (114) to carry on the wilting tests which showed the real value of the moisture equivalent determinations. In these later tests the centrifugal machine was considerably improved and its speed automatically controlled, while being cut down to give a pull of 1,000-gravity, since it was found that the higher tension extracted relatively little additional water. As the result of some hundreds of wilting tests and comparisons with the moisture equivalents of the same soils, it was found that from light sands to the heavier clays a linear relation exists between these two measures, which is expressed by the formula:

$$\text{Wilting coefficient} = \frac{\text{moisture equivalent}}{1.84 (1 \pm 0.007)}$$

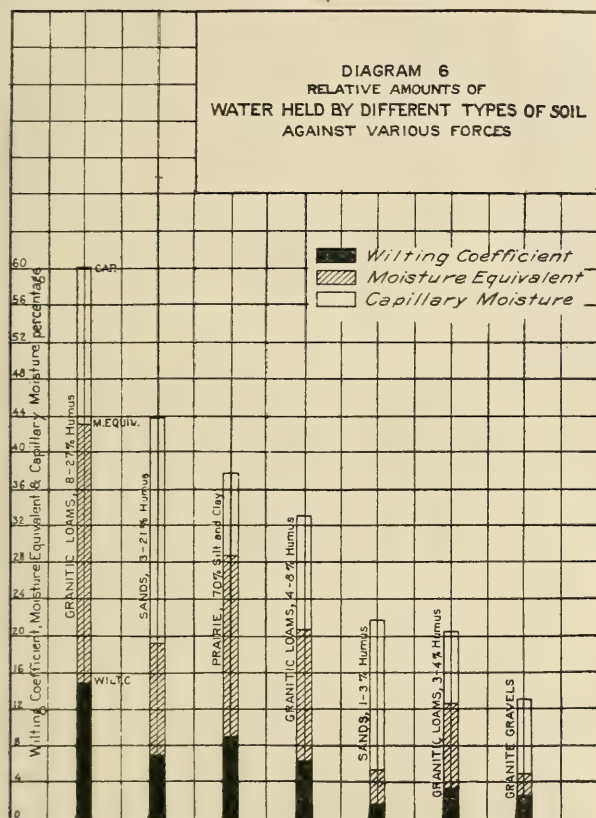
Or, in other words, there is a probable error of less than 1 per cent in this average relationship. Single determinations, however, show a probable variation of 2.9 per cent of the wilting coefficient, as measured by this direct means.

This work, though extremely thorough, was confined wholly to soils encountered in agricultural regions, and while these varied between 1.6 to 57 per cent moisture equivalent, they were undoubtedly more homogenous than forest soils in general, and lacked the complicating features of both rocks and large quantities of organic matter. It is not desired to suggest that, if this method were readily applicable to forest soils, and if experimental error both in wilting coefficient and moisture equivalent determination could be largely eliminated, the general relationship would be found different in the case of forest soils. Unfortunately, no one has made sufficient use of the moisture equivalent, in connection with wilting tests on forest species and forest soils, to determine whether the formula of Briggs and Shantz holds good. It is hardly to be doubted, however, that a formula must be worked out for each species, or the species of each general climatic region. Also, there is little doubt that occasional soils will be found in which, owing to exceptional alkalinity or acidity, the wilting coefficient is extremely high, and hence the formula breaks down.

In connection with the capillary moisture determinations by Bates (105), data on corresponding moisture equivalents have also been given in Tables 2 and 3. These, as pointed out, were determined on samples which had just passed through the capillarity tests. The 4 by 5½ inch soil cans were placed in a machine of such speed and radius as to develop a centrifugal force of 100-gravity, the radius being computed to the center of the 5-inch column of soil. Ordinarily, 30 minutes of revolution suffices to extract the free water susceptible to this force, but with a heavy clay an hour may be required.¹¹

¹¹ In order to show the importance of the time element, where such large masses of soil are being treated, and also to illustrate the very great difference between the water-holding powers of sand and clay, two samples were weighed repeatedly after short periods on the centrifugal machine. The one sample consisted of very fine, thoroughly washed sand from granitic soils, the other entirely of silt and clay from innumerable sources, the clay probably not constituting over one-fourth of the whole mass. Both samples had previously been compacted by centrifuging, so that the rapid loss of moisture in the first period can not be ascribed to loose structure. The test was somewhat complicated by a freezing atmosphere which, in fact, necessitated cessation before an end point for either soil was plainly reached. From a mass of soil of about 1,070 grams in either case, the sand gave up in 80 minutes 276.3 grams of water, of which 230.7 grams (84 per cent) was released in the first 2½ minutes of centrifuging. The corresponding figures for the silt and clay were 76.2 grams, and 12.7 grams or 17 per cent. In the last 20 minutes of the 80-minute period the loss for the sand was 3.1 grams and for the clay 12.8 grams.

The results of tests so made confirm the idea which was given by Table 2, namely, that the relation of the moisture equivalent, as determined by a force of 100-gravity, to the wilting coefficient, may depend a great deal on the type of soil. To make the reason for this clearer, the data of Table 2 have been further grouped in Table



4. while diagram 6 assists in visualizing the relations. Data for other types of soil have also been introduced. In the case of the sands and the prairie clay, the conditions under which the wilting coefficients were determined were perhaps conducive to slightly lower values than in the other groups. This, however, will affect the comparisons of wilting coefficients with capillary moisture and moisture equivalents, about equally.

TABLE 4.—*Moisture equivalents in several types of soil in relation to capillary moisture and wilting coefficients.*

Description of group.	Mean capillary moisture.	Mean moisture equivalent.	Mean wilting coefficient.	Mean ratio M.E./C.	Mean variation.	Mean ratio W.C./M.E.	Mean variation.	Mean ratio W.C./C.	Mean variation within group.
9 Michigan and Nebraska sands; humus not over 3 per cent.....	<i>P. ct.</i> 21.82	<i>P. ct.</i> 5.49	<i>P. ct.</i> 1.73	0.253	0.055	0.320	0.035	0.080	0.016
5 Michigan and Nebraska sands; humus 3 per cent to 21 per cent.....	43.78	19.24	6.99	.407	.090	.357	.028	.152	.023
9 Pikes Peak gravels; humus 2.1 per cent, clay 3.7 per cent (maximum).....	13.13	4.92	2.58	.377	.040	.530	.038	.200	.030
3 granitic loams (spruce); 3 to 4 per cent humus.....	20.47	12.62	3.36	.621	.042	.266	.006	.165	.014
3 granitic loams (spruce); 4 to 8 per cent humus.....	33.09	20.76	6.36	.632	.054	.307	.030	.193	.010
4 granitic loams (spruce); 8 to 27 per cent humus.....	60.13	43.09	14.86	.692	.077	.348	.066	.242	.051
1 prairie clay; 70 per cent silt and clay, very little humus.	37.77	28.79	8.90	.762	-----	.310	-----	.236	-----
Average of groups.....	-----	-----	-----	.533	-----	.348	.034	.181	.021
Mean variation between groups.....	-----	-----	-----	.1624	-----	.0543	-----	.0419	-----

1. There are three outstanding facts in connection with these data, clearly shown by the diagram. The first of these is that the two groups of sands show an extremely large proportion of the capillary water removable by the force of 100-gravity, and correspondingly low wilting coefficients. This speaks for the light hold which the sands have on their moisture, when even approaching saturation.

2. The second conspicuous fact is that, with the exception of the granitic gravels, the wilting coefficients and moisture equivalents rise and fall somewhat proportionately. The gravels have the smallest capacity for capillary water, a very weak hold on a large part of it, and a strong hold on the remainder. This is partly caused by a small quantity of clay derived from the feldspar, but more largely to the fact that the feldspar is itself somewhat permeable. Coarse cleaned gravel of this type has been shown to have a capillarity of only 2.90 per cent, but a moisture equivalent of 1.70 per cent. It seems likely that practically all of the latter would be non-available.

3. Another important point to be noted is the very small amount of water removable from the prairie clay by the moderate centrifugal force, and the correspondingly high wilting coefficient.

4. Finally, although the influence of humus is somewhat obscured by the fact that increasing amounts of it in one general soil type are usually accompanied by increasing amounts of silt and clay, it seems fairly certain that the humus does not yield up its moisture any too readily and that it may tend to make the wilting coefficient relatively high by preventing capillary movement to the roots. It must also

be remembered that, while the table indicates three times as much water-holding capacity in the granitic loam of high humus content, the actual increase over the same type of soil with little humus is only about 65 per cent on a volume basis.

The sum of these various effects of different soil properties on the moisture-holding properties is shown in the final line of Table 4, where it is clearly indicated that there is a closer parallelism between wilting coefficients and moisture equivalents than between wilting coefficients and capillarity. Eliminating the granitic gravels, the average variation of the group ratios is only 7.5 per cent from a mean value W. C./M. E. of 0.318. The explanations given, moreover, all tend to confirm the belief that the moisture equivalent obtained with a much greater centrifugal force would give a still closer index to the wilting coefficient of any of these types of soil.

The *hygroscopic coefficient* is an expression of the amount of water held by a soil after a limited exposure to saturated water vapor under certain conditions. As in the case of the capillary moisture measure, it appears that Hilgard was the first to make practical use of the absorption powers of soils, to compare them generally as to physical properties, and to obtain an approximate measure of their wilting coefficients. More recently Alway (102, 103) has done a large amount of work on this subject, using Hilgard's methods very largely, but also investigating many possible sources of error in the routine treatment of samples.

It is a very well-known fact that a soil is never entirely devoid of moisture if dried in the air for an indefinite period. On the contrary, if atmospheric conditions did not fluctuate so rapidly there would be at all times an amount of moisture in the soil somewhat proportionate to the amount of vapor in the atmosphere. The amount so held is a measure of the soil's hygroscopicity, but not a useful measure because of the changing conditions of the atmosphere.

Similarly a soil undoubtedly still possesses some hygroscopic moisture when dried in an oven at, say, 100° or 110° C. The only way in which the soil can eventually be robbed of all its moisture is by drying in a vacuum, by means of which the constant withdrawal of the atmospheric vapor is assured. For practical purposes, however, drying in an ordinary atmosphere at 110° C. gives a good basis for moisture calculations, since at that temperature the vapor in the atmosphere will be very much rarefied in comparison with its saturation capacity. This point is mentioned because it is not infrequently noted, in drying large samples, that they may gain moisture in the hot-air oven if there is a decided increase in atmospheric moisture. To avoid appreciable errors it has been found necessary to avoid final weighings of oven-dried samples on excessively moist days.

The discovery that within certain limits the moisture of the soil follows the laws of osmosis, or more precisely speaking, the laws of dilute solutions with respect to its freezing point, has naturally led to the idea that the soil solution might also be considered as having a definite vapor pressure at a definite osmotic concentration. If this were true, then a soil placed in a moist atmosphere should give off or absorb vapor, according to whether its original solution represented a lower or higher osmotic pressure than that represented by the atmosphere of vapor in which it was placed. Furthermore, if this vapor pressure manifested itself properly and in accordance with the laws of solutions, then, through vapor transfers, one soil or a hundred soils simultaneously might be brought into vapor-pressure equilibrium, and thereby into osmotic equilibrium, with a solution whose osmotic pressure is readily determined; and the moisture contents corresponding to such osmotic pressure might then be readily measured for one or all of the soils. This plan was conceived as a possible means of avoiding some of the difficulties of the freezing-point method of osmotic determinations, which are especially bothersome in treating coarse soils. That the theory is correct may hardly be questioned now, and full discussion of the available data will be given later. This subject has been mentioned here because of its possible bearing on the hygroscopic coefficient determinations. It is rather readily seen that, if the laws of solutions prevailed under all conditions of soil moisture, a soil exposed to completely saturated water vapor should go on absorbing moisture indefinitely, because the dilute solution of the soil would always stand for some osmotic pressure, while saturated water vapor would stand for none at all.

Whether this does not occur in the hygroscopicity tests because of the failure to create a completely saturated atmosphere, or because there is a sharp line between the behavior of water vapor in the soil and liquid water, is for the future to decide. That it probably has no practical bearing on the hygroscopic coefficient under the empiric conditions set for that test, is perhaps enough in itself. It will help to clarify the matter if it is remembered, first, that Bouyoucos (109) has shown that at about the moisture content at which wilting occurs, the water of the soil ceases to behave as a liquid and refuses to freeze; and secondly, that Briggs and Shantz (114) have shown that the hygroscopic coefficient falls considerably below the wilting coefficient, the former being usually about 0.7 of the magnitude of the latter.

Since the determination of the hygroscopic coefficient begins with air-dry soil, it does not deal with liquid water in the soil, but more probably with water molecules more or less separated, like individual vapor molecules.

The conditions under which the hygroscopic coefficient should be determined, as most recently worked out by Alway, Kline, and McDole (103), are briefly as follows:

1. The absorption box is of wood, 12 by 9 by 8 inches, the interior surfaces being paraffined to prevent absorption of water and warping. Larger boxes were found to be more difficult to keep saturated.

2. In the bottom of this box is placed a snug-fitting galvanized-iron tray, 3 to 4 inches high, to hold the water. The walls of the box are then lined with blotting paper, the edges of which project into the vessel of water. This insures rapid dissemination of vapor through the interior.

3. A wooden table is held by metal supports, 1 to 2 inches above the surface of the water in the tray. On this table are placed the two trays which hold the soil samples.

4. Metal trays are accepted as most satisfactory, because they absorb no moisture and hence do not retard absorption by the soil. These trays are of aluminum or copper, 7 inches long, 5 inches wide, and 0.75 inch deep.

5. The soil is carefully sifted over the bottom of the tray to a depth of 1 millimeter. This naturally precludes the use of coarser material. It was found that there was little or no change in soils from careful grinding which would barely permit the coarser particles to pass a 1-millimeter sieve. It was also found that oven drying at 105° to 110° C. did not appreciably affect the absorbing capacity of any of the soils tested. In any case, however, previous drying should be avoided when possible.

6. The exposure to vapor in the boxes is for 24 hours. At the end of this period the soil tray is removed from the box as quickly as possible and emptied into a stoppered weighing bottle, since exposure to the air beyond a few seconds would cause appreciable loss of moisture.

7. Undoubtedly the most important consideration in securing reliable results is a suitable room. This must be, in most cases, a cellar room not subject to daily fluctuations of temperature or heating from one side, or even to localized heating from bright light. These precautions are absolutely vital, if condensation is to be prevented. As a matter of theory, it is altogether probable that the need is to prevent even momentary complete saturation of the vapor in proximity to the soils, since this might give rise to the creation of liquid moisture in them, and entirely alter their condition.

8. A temperature of about 60° F. may be considered a standard. At a lower temperature there will be fewer water molecules reaching the soil, and, necessarily, a slower rate of absorption.

Under these circumstances fairly constant results may be expected in hygroscopic coefficient determinations. In the absence of any other

results reference is again made to the comparisons made by Briggs and Shantz between hygroscopic and wilting coefficients. In 17 tests, with soils varying from 0.9 to 16.5 per cent wilting coefficient, they found the ratio of hygroscopic to wilting coefficients to be on the average 0.680, with a probable error, or variation, in any single determination of about 7.1 per cent of the wilting coefficient. It is to be noted that the hygroscopic is so much lower than the wilting coefficient that serious error would result from considering them as interchangeable, though this proposal has sometimes been made.

CALCULATION OF THE AVAILABLE MOISTURE.

As has been stated, when the current moisture of the soil has been measured, and the nonavailable has been measured in the laboratory by the direct method of wilting tests, or indirectly through the capillary moisture, moisture equivalent, or hygroscopic coefficient, it is then only necessary to subtract the wilting coefficient from the whole moisture to have a measure of the amount of water which, under the most favorable circumstances, will be available for growth. For example, if in sand and clay, respectively, the whole moistures are 10 and 20 per cent, and the wilting coefficients of these soils are respectively 2 and 15 per cent, then it is evident that in the sand there is 8 per cent available moisture, and in the clay 5 per cent, or $A = M - WC$. The use of the last figures is certainly far more expressive of the relative conditions in the two soils than would be the use of the whole moisture figures, although, on account of varying concentrations of salts, even this figure for the available moisture does not give a direct means of comparing the moisture conditions of radically different soils.

Of course, if the measure of available moisture is to be used most fully as an index to supply, the percentage should be transposed finally into cubic centimeters per cubic meter, or any other measure of soil volume.

This is very readily done if the apparent density has been determined, as in the large capillary cans described, where the apparent density is obtained by dividing the dry-soil weight, in grams, by the volume in cubic centimeters, which is approximately 1,030 cubic centimeters (usually less after centrifuging).

Carrying the volume idea still farther, in studying any plant or group of plants it is obviously desirable to know how much soil surface can be drawn upon. Thus a yellow pine on a dry site may actually have a much greater supply of moisture than a crowded spruce on a moist site. Consideration of this point of view will lead to the conclusion that soil moisture figures, as ordinarily given in percentages of the dry-soil weight, have almost no significance

ecologically. Both area and depth of soil which contribute to a given plant must be known.

AVAILABILITY OF THE MOISTURE.

As already stated, it is intended to confine this term "availability" to the simple relation between the whole moisture and the available moisture. The term can not be an exact expression of the rate at which the plant will be able to obtain water, since such rate depends on conditions within the plant as well as those without; or, in brief, on the need of the plant for water. It should, however, have greater value than a bare measure of whole moisture, or even of available moisture in percentage of dry soil weight as an expression of a condition of the soil. Its value is predicated on the assumption that, at the wilting point, a given plant is probably exerting a fairly definite osmotic pressure in its effort to obtain water, and that at this time the osmotic pressure of the soil water is also definite and the same as that in the plant. This is evidently not the case if the wilting coefficient is as low as the point at which both the water and solutes become adsorbed by the soil colloids, for at this point the osmotic pressure becomes infinitely large. For this reason the proposed measure of availability may have only limited usefulness, but should at least serve as a stepping stone to the next and more definite proposal.

If, for example, it is assumed that when a plant wilts it is exerting an osmotic pressure, P , of 100 atmospheres, then supposedly at the same time (that is, in the condition expressed by the wilting coefficient) the soil is exerting an opposing force, P' , also represented by 100 atmospheres. If, then, an amount of water equal to the wilting coefficient is added to the soil, the soil solution, roughly speaking, has been diluted to one-half its previous strength, and there is a differential in favor of the plant of 50 atmospheres. Since the starting point was 100 atmospheres, this situation, or the availability for this particular plant and soil, may be expressed as $50/100$ or 0.50. Similarly, when the moisture content is three times the wilting coefficient, $P'=33$ atmospheres, the differential is 67 atmospheres, and availability is 0.67. It is seen that this is readily expressed by

$$Av. = \frac{M - WC}{M}$$

giving availability numerical values somewhat proportionate to the osmotic pressures in favor of the plant.

THE COEFFICIENT OF AVAILABILITY.

As already suggested, the ability of the plant to supply itself with water would seem to be measurable in terms of the differential

between the osmotic pressure within the plant and the antiosmotic pressure exhibited by the soil moisture, with an allowance for the distance through which this force must operate. This same basis was used in the preceding section as a rough means of showing changes in the soil condition, but without any allowance for changes in the absorbing power of the plant which occur with its loss or gain of water, or without considering the factor of height and distance as it may affect tall trees.

In attempting thus to express the availability of water to the plant, in precise terms or osmotic pressures, currently for any condition that may be encountered in the soil or plant, it is necessary to determine the osmotic pressure of the soil or plant quickly and accurately.

The osmotic pressure of an aqueous solution is determined by the increase in its boiling point over that of pure water; by the depression of its freezing point; by the decrease in the vapor pressure over the solution; and, possibly, by the increase in the latent heat of vaporization. It is only recently that investigations of the last have been made, so that there is no known formula which would make this process available.

Within the limits of so-called dilute solutions a rise of 1° C. in the boiling point represents an osmotic pressure of about 57 atmospheres; a depression of 11° C. in the freezing point indicates $P=12.05$ atmospheres, and a depression of 1 per cent in the saturated vapor pressure over the solution, the temperature being the same, indicates about 12 atmospheres pressure. These approximate figures permit us to judge of the practical utility and accuracy of different methods.

It may also be useful at this point to refer to the fact that in pure solutions, such as may be used in the vapor-transfer method or in plasmolytic tests on tissues, the osmotic pressure is very readily determined by the concentration of the solution, in terms of the molecular weight of the solute, provided the solute is chemically pure and anhydrous. According to Nernst (134) the "molecular lowering of the freezing point" for water is 18.4° C.,¹² or 1.84° C. when 1 gram molecule of the substance is dissolved in a liter of water. A 1-molecule solution, therefore, stands for 22.12 atmospheres osmotic pressure.

From these data it would seem that the boiling-point method would insure the greatest precision in osmotic pressure determina-

¹² More recent investigations reported by Jones 128 show that the molecular lowering may be twice this amount in the case of salts which are dissociated by water into two ions. Freezing-point determinations should quickly decide this, in case of doubt.

tions, were it not for the effect on the boiling point of the character of the vessel itself, of gases in the liquid, and of solid particles which form nuclei for steam bubbles. It is also self-evident that the boiling-point method is not applicable to soils, and hardly more applicable to plants unless the sap has been separated from the pulp, which, under certain circumstances, as in the treatment of conifers, may be impossible of attainment.

The freezing-point method comes next in order, and has been considerably used; though, at this stage, it is well to mention that the foliage of coniferous trees frequently becomes so dry that a definite freezing point can not be determined, probably because of the lack of conductivity in the mass, which is such that each particle of the pulp may freeze without affecting the rest of the mass quickly.

The vapor-pressure method does not look so promising, because of the technical difficulties in the way of any precise determination of vapor pressure. However, the complicated apparatus necessary for the direct determination of a vapor pressure may be done away with if instead the determination of vapor pressure is made in a vessel by means of a solution which is in equilibrium with that vapor. This method especially commends itself in the treatment of soils because of the possibility of preparing them and retaining them during treatment in a state of compactness and granulation approaching the natural. It does not seem so applicable to plant tissues because of the danger of fermentation and enzymic action during the treatment.

The determination of osmotic pressures in plant cells by plasmolysis, while evidently useful for the examination of restricted areas, such as the epidermis, and possibly useful for any tissues which are exceedingly dry, does not recommend itself for general purposes because of the large amount of manipulation necessary and the experimentation required to find the balancing solution. This method, of course, necessitates the observation of individual cells under the microscope, when placed in media of various osmotic concentrations.

Osmotic Pressure of Plant Tissues.

Dixon and Atkins (119), in 1913, were apparently the first to use the then developing theoretical knowledge of the behavior of solutions as a means toward looking into the internal conditions of plants. In the citation given they deal at length with the method of extracting sap from plant tissues for the purpose of freezing-point determinations.

Hibbard and Harrington (126), in 1916, and Harris, Lawrence, and Gortner (123), in the same year, followed this work with further

studies of the method of determining the freezing point of cell saps, and also applied this knowledge to the study of plants under various habitat conditions. The latter were probably the first to point out that the osmotic pressure of the cell sap varied rather directly with the dryness of the habitat. They also showed that trees and shrubs possess higher pressures than the lower and shorter lived forms of vegetation, which furnishes the basis for considering height as a factor affecting the osmotic pressure in the leaves.

McCool and Millar (131), 1917, experimented with unpressed plant tissues and obtained practically the same results as when the extracted saps were used. This was a distinct step forward in simplifying the process, and therefore no attempt is made to describe the method of sap extraction. McCool and Millar found it only necessary to macerate slightly the material with a stiff wire, in the freezing tube. These investigators also brought out much new information on the changes in osmotic pressure in the leaves with atmospheric changes, and the close correlation between root pressures and conditions of the soil moisture, the former being little influenced by atmospheric conditions.

Bates (105), in 1917, seeking an explanation of the great difference in the transpiring capacity of different species of tree seedlings, and not being equipped with freezing-point apparatus, obtained the sap density of the aerial portions of whole seedlings by grinding them in a food grinder, extracting the water-soluble substances, filtering the liquid, and then drying the water-soluble solids and the washed pulp separately. The weight of these two, when deducted from the original weight of the plant, gives the weight of the original solvents, and the "sap density" is expressed by the ratio between solutes and solvent. These first results were found to have a close relation to the transpiration rates that had been observed, and it was therefore concluded that sap density might very largely serve as an automatic restriction on transpiration.

Although realizing that an expression of osmotic pressures would give a more reliable basis for comparing the species, this was not undertaken for some time, since it was desired to establish first the importance of the sap density as a measure of the condition of the plant and its response to various atmospheric conditions. This work has been pursued to some extent.¹³ It is only desired here to state that, within the limits of experimental error, the osmotic pressures shown by a number of the conifers appear to be the same when the sap densities by the above method are the same. Considering all of

¹³ "Forest Types of the Central Rocky Mountains," by C. G. Bates. Unpublished report.

the species. the following correlation between the two measures is given tentatively:

Sap density.	Osmotic pressure.
<i>Per cent.</i>	<i>Atmosphere.</i>
5	4.5
10	10.0
15	15.7
20	22.4

For rough approximations, the osmotic pressure in atmospheres may be considered equal to the sap-density percentage for plants of this class. It is probable that further data will bring out specific differences worthy of consideration. It is, therefore, believed that where freezing-point determinations are impracticable because of lack of apparatus, or of freezing mixtures; or when, as frequently happens with the foliage of conifers, the material is so dry that even with grinding it lacks free moisture, so that a distinct end point can not be secured, the sap-density method may be of very great assistance.

After considerable experimentation with a number of methods giving essentially the same results, the following simple practice has been developed, which is designed primarily to eliminate the need for evaporating the large volume of water used in extracting the solutes; it also greatly reduces the opportunity for loss of material during the operation.

1. The plant material, usually consisting of the more exposed and consequently the drier portion of the needles, is secured by carrying into the field the desired number of wide-mouthed liter flasks, a funnel, and a pair of shears. The plant, or branch of a tree, is held over the funnel, and the leaves are snipped off in sections not over one-half inch long, the outer one-half to two-thirds of all needles being taken. When 10 to 15 grams of material has been secured, the flask is stoppered. As soon as a collection has been completed, the flasks are taken in and weighed with their contents, the flask weights having previously been recorded. Confusion may be avoided by making all weighing with the stoppers removed.

2. The flasks are now placed in the drying oven for a period of not less than 12 hours. It will usually be found convenient to have the specimens ready for extraction early in the morning. At this stage the weight of flask and dry contents is secured, and by the difference between this and the earlier weight, the original water content is obtained directly.

3. Each flask now has added to it distilled water to the extent of five times the weight of the green plant material and is then again placed in the oven for an hour, the temperature attained in this time

being practically that of boiling water, which will greatly facilitate the diffusion of the solutes. While this warming is being accomplished, a filter may be prepared, corresponding to each flask. The filter papers are dried and weighed before using, and their weights credited to the samples with which they will be used. At the end of the hour the liquid contents of each flask are poured into their appropriate filters.

4. Water is again added to each flask, in the same amount as before, and the process repeated. After the third extraction, with possibly a little cold rinsing of the pulp, filter, etc., the filter, with whatever solids it has accumulated, is placed in the flask, and this is returned to the oven for its final drying. After this, making allowance for the filter-paper weight that has been added, the loss of solutes is readily computed. It should also be realized that this loss will include a small proportion of water which was hygroscopically held by the solutes in the previous drying. Such loss, however, will possibly compensate for solutes not removed. While the three extractions, theoretically, should remove more than 99.9 per cent of the solids, it is probable that they fall appreciably short of this.

Since it is believed that investigations along this line will develop increasing importance in forest ecology, it seems advisable to make available a table of osmotic pressures for freezing-point depressions to 5.999° C., as worked out by J. A. Harris and published in the *American Journal of Botany*, 2:418-419, 1915. This is an extension of the work begun by Harris and Gortner in 1914. The table will be found in the appendix.

Of almost equal ecological importance with the increase in osmotic pressure and absorbing capacity which accompanies greater concentration of the cell sap, is, perhaps, the very great decrease in the probable rate of evaporation from the leaves. It is especially desired to call attention to this, since the earlier announcements of the findings of physical chemistry have led many biologists to believe that a considerable change in the osmotic pressure of the plant solution could have little effect on evaporation. Thus Livingston (130), in 1911, argued that the greatest concentration of the cell sap would only create a depression of 10 per cent in the vapor pressure over the solution, and consequently could have no important effect on the evaporation rate.

As early as 1915, Bates (105) had observed in the artificial drying of pine cones, for which a calorimetric kiln was used, a very great increase in the amount of heat consumed as the drying advanced. In certain instances this was nearly three times as great, per unit of water evaporated, in the final stages as when beginning with very green cones. When, therefore, he found, in 1917, a great decrease in the transpiration rate of those species of conifers which showed

the highest concentration of the cell sap, he was led to investigate this matter further. Finding nowhere any reference to experiments on the latent heat of vaporization of solutions, and believing that the conception of the fixed nature of that quantity for water was based upon the fact that the condensation of steam had always been employed to determine it, he has been led to perform a number of experiments with solutions and with distilled water.

The most important and convincing of these shows that at the respective boiling points of water, and various solutions up to the point of saturation (for sodium chloride), the latent heat of vaporization, determined directly by means of an electric heating element, is practically a constant, though perhaps varying inversely as the absolute boiling point. Thus a saturated salt solution whose boiling point is 7° above that of water and whose osmotic pressure is theoretically about 400 atmospheres, requires only 4 per cent less heat, per unit of water evaporated, than does pure water. This, however, does not solve the problem, as will be seen from the fact that when placed over a steam bath the saturated salt solution evaporates at a rate of less than 5 per cent of that for pure water. There is in the problem, therefore, very evidently some factor besides vapor pressures and latent heats of vaporization when an external supply of heat is concerned. It appears to be a matter of conductivity and possibly also of convection. Further investigation of the problem is urgently needed.

Method of determining freezing points.—Since, as has been stated, the treatment of the leaves of forest trees, especially conifers, is likely to present some complications because of the extreme dryness which they sometimes show, it is believed the whole-tissue method of McCool and Millar (131) is likely to be ineffective. Hibbard and Harrington (126) are therefore quoted here on the process used by them and involving grinding of the frozen tissues. From this basis any investigator will certainly be able to devise modifications to suit his special conditions.

The apparatus used in our tests was the Beckmann outfit ordinarily used for such work and described in books on physical chemistry, consisting of a Beckmann thermometer, freezing tube, outer jacket, and a battery jar containing the freezing mixture. The freezing point of distilled water was taken as zero, and the lowering of the freezing point of the pulp was obtained by subtraction. When determining the freezing point of distilled water an electric stirring device was used consisting of battery, metronome, magnet, and platinum stirrer, but this was not employed in determinations made upon pulps. The pulp was allowed to undercool about 1° , after which the beginning of solidification was brought about by rotating the thermometer backward and forward a few times in the pulp. When the undercooled mass of pulp was thus disturbed the temperature began to rise almost immediately and soon came to rest, after which the thermometer was tapped several times and the

final reading then taken. This reading was considered as the freezing point of the pulp tested. Correction for undercooling has not been applied, since the undercooling was always the same. Since, as has been especially emphasized by Shive,¹⁴ the external air temperature exercises a marked influence on the apparent depressions of the freezing point obtained by means of the Beckmann apparatus, the freezing of the pulp or expressed juice must always be carried out with approximately the same temperature of the surrounding air as prevailed during the determination of the freezing point of distilled water used for comparison with that of pulp or juice. The simplest way to avoid possible sources of error in this connection is to make a freezing-point determination on distilled water for each external air temperature at which pulps or juices are tested. Then the lowering for any test is considered as the difference between its freezing point and that obtained on distilled water with the same room temperature.

The property of the solution upon which its maximum possible osmotic pressure depends is approximately measured by its freezing point lowering, and this property may be expressed in terms of pressure. Thus, according to the formula of Lewis,¹⁵ $\Pi = 12.06\Delta - 0.021\Delta^2$, where Π is the maximum osmotic pressure, in atmospheres, at the freezing point of the solutions, and Δ is the lowering of the freezing point in centigrade degrees, below that of distilled water. With the aid of this formula Harris and Gortner¹⁶ have prepared a table of the values of Π for the range, $\Delta = 0.001^\circ \text{C.}$ to $\Delta = 5.999^\circ \text{C.}$ This table has been employed in our deductions.

At the beginning of the work the material to be used was first ground and then frozen, but it was difficult to prevent some loss of sap in this way, and difficulty was also encountered in getting a perfect mixture of the material after thawing, since much of the sap had left the cells on grinding and had settled to the bottom of the mass. Consequently, it was found better first to freeze the material and to grind it afterwards. In the earlier tests this preliminary freezing was carried out in large test tubes immersed in a mixture of salt and ice at a temperature of from -12° to -17°C. Sometimes during cold weather the material was placed out of doors overnight for the preliminary freezing. In the remainder of the work it was frozen by carbon dioxide and ether. Carbon dioxide was obtained in the solid state by allowing the compressed gas to escape from the supply cylinder into a small cloth bag. The material to be frozen was placed in a beaker and completely covered with solid carbon dioxide. A small amount of ether was then added, until complete freezing had taken place. A temperature of approximately -120°C. may be obtained in this way.

The tissue is reduced to a finely divided condition by grating or grinding in a food grinder. The ground material must be quickly and thoroughly mixed before sampling, since as would be expected, and as has indeed been found by other investigators, not all parts of a given organ give the same concentration of sap. Unless great care is taken in mixing, two or more samples of the same pulp do not have the same osmotic concentration.

Samples are placed in the freezing tubes and allowed to thaw completely before the determination of the freezing point is made. When the tissue is

¹⁴ Shive, J. W., The freezing-points of Totttingham's nutrient solutions, *Plant World* 17: 345-353, 1914.

¹⁵ Lewis, G. N., The osmotic pressure of concentrated solutions and the laws of the perfect solution. *Jour. Amer. Chem. Soc.* 30: 668-683, 1908.

¹⁶ Harris, J. A. and R. A. Gortner. Notes on the calculation of the osmotic pressures of expressed vegetable saps from the depression of the freezing point, with a table for the values of Π for $\Delta = 0.001^\circ \text{C.}$ to $\Delta = 2.999^\circ \text{C.}$ *Am. Jour. Bot.* 1: 75-78, 1914.

Harris, J. A., An extension to 5.999°C. of tables to determine the osmotic pressures of expressed vegetable saps from the depression of the freezing point. *Amer. Jour. Bot.* 2: 418-419, 1915.

ground and pressed before the preliminary freezing many serious changes may take place; enzymes may be liberated, many new chemical reactions may be brought about, and the solutions may change in various physical ways. After thawing, the material should be stirred with a glass or suitable wooden rod to expel all air bubbles. Thawing may be completed within 15 or 20 minutes at most, and the possibility of chemical change is thus very greatly reduced. When thawing is complete, the thermometer is inserted, the tube is placed in the freezing mixture, and the material allowed to reach a temperature about 1° below its freezing point. Solidification is then brought about, as has been stated, by turning the thermometer backward and forward a few times to create a slight disturbance in the pulp. It has been found in practice that much more satisfactory results are obtained if the material is thus allowed to undercool about 1° than when solidification is brought about with less undercooling. In the latter case the mercury rises to the freezing point much more slowly and the determination of this point is consequently more difficult.

Osmotic pressure in soils.

Although it is possible to remove the soil solution from the soil and to determine its osmotic pressure by the freezing-point method, this will fall far short of the desired end, which is to determine how the water behaves in the presence of the capillary forces and adsorption tendencies of the soil particles and colloids. As has been suggested in the introductory paragraphs to this chapter, these influences may run parallel with the influences of dissolved salts in the soil water.

The freezing-point determinations for moist soils are so similar in method to those for plant pulps that it seems unnecessary to describe them here in detail. The reader is especially referred to the description given by Bouyoucos (107). It would seem that the fundamental consideration in testing a given soil at various moisture contents is to have samples very evenly wetted. This is accomplished by placing the sample in a moisture-tight jar and, after thorough shaking, allowing it to stand one or more days, so that the moisture is evenly distributed and has ample opportunity to be adsorbed. While it is possible to use measured amounts of water in wetting the soil, it is probably safer procedure to take moisture samples at the same time that samples are taken from the jar for freezing tests.

Vapor transfer in soils.—The vapor transfer method is the only other method of osmotic determination which appears feasible for soils, and where time is not an important element, it is believed to be preferable to the freezing-point method because of the possibility of treating soils in their natural states. It should be understood, however, that the value of the method is as yet theoretical rather than proven.

The work of Alway (103) and Hilgard (125) on the hygroscopic coefficient of soils has already been mentioned, with the suggestion that since the moisture boxes used could not completely prevent the

vapor from escaping, their results are not indicative of those to be expected when vapor pressures are maintained in true equilibrium with solutions of reasonable osmotic pressure. As has been stated, a solution showing 12 atmospheres pressure will be in equilibrium with vapor 99 per cent saturated, and even this degree of saturation, it is believed, would be extremely difficult to maintain except in a fully sealed vessel.

On the other hand, Patten and Gallagher (136) have carried out experiments, both on absorption of vapor and evaporation from soils, in "desiccators" which are assumed to be similar to the bell jars mentioned hereafter, and which, while usually not strictly vapor proof, approach much nearer to the ideal condition. Patten and Gallagher, both in their review of earlier work and in their own experiments, have established a number of salient points which assist in the proper conception of the relation between vapor (or, to a certain extent, gas) molecules and solid particles, such as those of the soil. Schübler¹⁷ and Davy¹⁷ are quoted as having shown that, in general, the finer the texture of the soil and the greater its content of humus, the higher is the absorption capacity of soil for water vapor. These results, while actually referring to the initial rate of absorption, are fairly indicative of the forces with which various soils attract water vapor. Von Dobeneck¹⁷ obtained similar results, though concluding that large grains absorbed more vapor per unit of surface than small ones. Each soil particle reacts upon vapor molecules independently, and each has a specific relation to different kinds of gases. Several investigators have decided that the absorption of vapor decreases with an increase in temperature, even though the absolute vapor pressure increases proportionately. Patten and Gallagher have carefully proven this. Hilgard's contrary finding may be explained on the basis that he was dealing almost wholly with rate of absorption, and higher absolute vapor pressure should more quickly bring about equilibrium. Mason and Richards¹⁷ found that cotton fiber containing water resembles a solution in exhibiting a definite partial vapor pressure.

Patten and Gallagher's most important results have to do with the rates of absorption of vapor, and with evaporation, in the presence of various vapor pressures controlled by sulphuric acid solutions and vessels of water, within desiccators. The rate of absorption by dry soils increases, and the rate of evaporation from wet soils decreases quite regularly as the partial vapor pressure in the desiccator is increased. It is, however, evident in all of the results that as the vapor pressure approaches saturation the amount of absorption increases in greater proportion than does the vapor pressure. A number of the graphs are strongly suggestive of the idea that, if com-

¹⁷ For complete citations see Bureau of Soils, Department of Agriculture, Bulletin 51.

plete vapor saturation were attained, the absorption by the soils might be unlimited.

With partial vapor pressures over acid solutions, practical equilibrium was reached in all soils at the same ultimate moisture content, whether the soil was started in a moist or dry condition. Thus Sea Island cotton soil, which was the finest used, dried out at a vapor pressure of 17.90 millimeters (76 per cent of saturation) in 97 days from 55 per cent to 6.08 per cent moisture, and the same soil absorbed in the same period 5.6 per cent, starting from a dry condition. In the presence of a vessel of water the drying out was always very slow, and the fact that any drying whatever occurred is believed to be sufficient evidence that the atmospheres in the desiccator were not saturated, owing to the presence of the dry soils in the same atmospheres.

Finally, the energy effects of absorption must not be overlooked. Patten and Gallegher cite a number of investigations which show that the heat released when vapor is absorbed by a soil is in excess of the latent heat which is released when vapor condenses. This fact indicates that water held in the soil, like water held in a solution, is brought to a greater density than that in which only water molecules are attracting each other. This density can only be obtained through the release of additional energy.

Examined kinetically, then, the whole situation is fairly simple. Molecules of a gas or vapor repel one another, and this repulsion increases with the temperature and energy of each molecule. When a certain density is obtained in a volume of vapor, the so-called saturation density, the molecules may either return to the liquid from which they emanated or be compelled to unite with other molecules, starting condensation in the molecular sense. In the case of atmospheric vapor, solid particles, such as dust particles, may start condensation through their attraction for vapor molecules, which latter would otherwise repel one another too strongly to be brought together.

The same phenomena occur in the soil. A soil particle of given size, mass, and gravitational power can attract to itself a certain number of vapor molecules, this number depending upon the space available and the distance at which the vapor-molecules begin to repel one another, or the temperature and energy of these molecules. A vapor molecule which has been trapped, and has given up some of its energy in this process of "individual condensation," is relatively inert, but not so inert as the soil particle, and is still capable of repelling other molecules to some extent. The ultimate number of molecules that can be held in a given soil, therefore, must depend (1) primarily on the energy of the free molecules as governed by temperature; (2) on the area or surface of soil particles exposed.

such that vapor molecules remaining on said surfaces do not crowd one another; (3) on the size of the particles, the smaller particles having less gravitational power; and (4) on the extent to which the substances in the soil act as solids or crystals with only exterior surfaces available, as spongy masses capable of absorption, or as individual molecules each of which may attract and retain under partial control a sufficient number of molecules, so that in the aggregate the conditions are those of a liquid.

The factors that affect the rate of absorption are far less important, but might be briefly mentioned, as follows: (1) The size of soil spaces as affecting free passage of vapor molecules; (2) the number of chances for a given molecule in motion through a given space to encounter an attractive force too strong for it (this has to do with the number of particles per unit of volume, as well as size of air spaces); (3) the density of the soil particles; (4) the density of the vapor molecules as affected by temperature and whole pressure; (5) the conductivity of the soil, governing the rate at which the heat of condensation can be eliminated from the soil mass.

This examination of established facts and theory regarding vapor condensation in soils leads to the recent efforts by Bates (105) to show that the moisture of soils does exhibit a definite partial vapor pressure corresponding to that of a solution, and that the vapor transfer method has many latent possibilities. It should be stated that these investigations are not yet complete or convincing, but in some respects they have gone farther than any others and are worth mentioning at least as suggestions for further effort.

The vapor-transfer method of Bates.—In its simplest form the vapor transfer method is similar to the plasmolytic method in attempting to find a point of osmotic equilibrium between the soil moisture and solutions of known concentration. In this case equilibrium must be shown by the cessation of transfer of water, through vapor, from the soil to the solution, or the reverse. It would be possible to take a number of samples of a given soil at a known-moisture content and place them in relatively small chambers, each with a solution of different concentration from the others, and in the case in which there was no transfer from the soil to the solution or vice versa equilibrium would exist and the osmotic pressure of the soil water could be directly calculated from the known concentration of the solution.

In practice, however, it is far more feasible to place the soil sample of known moisture content in the vapor of a solution of approximately the same osmotic pressure, let the two come into equilibrium through vapor transfers, then compute the moisture content of the soil, the osmotic pressure of the solution, and the approximate original osmotic pressure of the soil on the assumption

that the osmotic pressure varies inversely as the moisture content. The latter is probably true only within rather narrow limits.

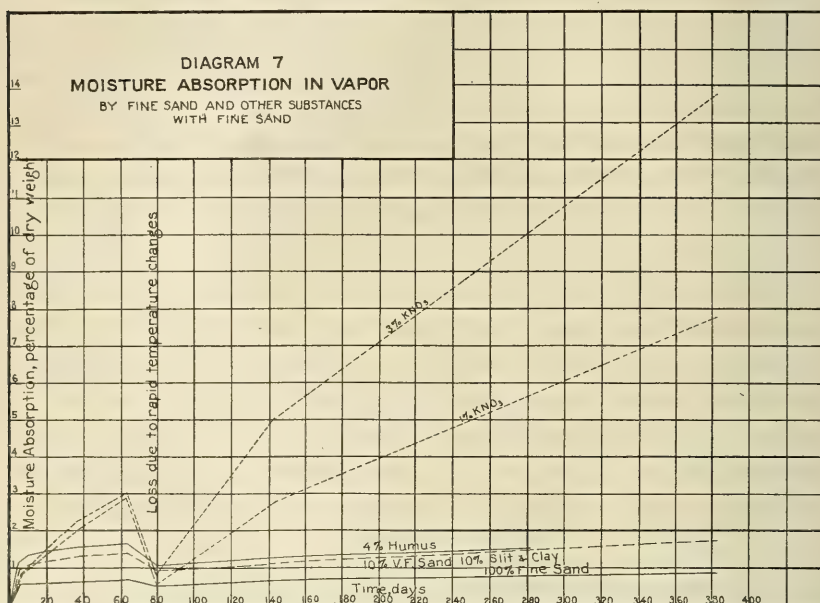
Further, since obtaining an equilibrium by vapor transfer is a slow process, it is desirable to be able to treat a large number of soil samples simultaneously. For this purpose a large-size bell jar, resting upon plate glass, may be employed. A pressure cooker, the cover joint being properly sealed, has also been found very useful. There may be one or more vessels of the solution, and as many vessels of soil as are desired, within the chamber. Using 2½-inch soil cans for soil containers and similar beakers for solutions, about 60 soil samples may be treated at once under a 14 by 12 inch bell jar. However, a great deal of evidence shows the desirability of a relatively large vessel for the control solutions, and a decrease in the number of soil samples.

It should be remembered that this treatment will only give the osmotic pressure for each soil at one particular moisture content, which will depend upon the total amount of water in all of the samples, as well as upon the concentration of the control solution, at the initiation of the test. To obtain a range of values for any soil, separate tests must be made under varying conditions.

The fundamental provision in such a test is that the vapor chamber should have a constant temperature and be evenly heated on all sides. To accomplish this most simply a deep excavation in the ground is desirable. The very gradual seasonal change of temperature in such a situation will not work any harm, since the vapor pressure within the chamber will adjust itself to such a change without necessitating any condensation. In the lack of this, a dark cellar may be chosen.

In proof of the theory that a soil solution would continue to absorb water indefinitely in the presence of saturated water vapor, and that, therefore, the hygroscopic coefficient as now known is a purely empiric quantity, a test has been conducted for slightly more than a year with clean sand and various modifications thereof which represent the different elements encountered in various types of soil. The sands and modified sands were all placed in the vapor chamber in an oven-dry state, together with a bottle of distilled water with linen wicks having about 10 square inches of evaporating surface. The successive weighings of samples and bottle indicate that some vapor is constantly escaping from the chamber, so that the vapor therein is never absolutely saturated. Early in the test it was found impossible to heat the chamber as evenly as desired in the cellar in which it was placed, so that it was removed for a time to an electrically heated incubator. Here the fluctuations, though small, were rapid and a slight overheating at one time caused a very severe loss from all samples, the chamber being unable to

hold the vapor under high pressure. The effect of this is seen in diagram 7, where some of the typical results are illustrated. In Table 5 is shown only the absorption for four periods, eliminating this period of general loss. Except this period, the exposure in the



cellar has been at temperatures between 0° and 10° C., which, it will be noted, are lower than have previously been employed.

For several of the soil types duplicates were run. The results, however, are so nearly identical in each pair that only the averages need be given.

TABLE 5.—*Absorption of water vapor by Nebraska fine sand, and modifications thereof.*

[Basis 100 grams dry matter in $2\frac{1}{4}$ -inch aluminum can.]

Number of samples.	Description of sample.	Absorption at end of—			
		5 days.	10 days.	63 days.	382 days.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
2	100 per cent fine sand, unwashed.....	0.56	0.58	0.68	0.80
1	100 per cent fine sand unwashed half-size ¹	.68	.68	.72	1.08
2	100 per cent fine sand, washed ²	.57	.62	.69	.79
1	90 per cent fine sand, 10 per cent very fine sand.....	.51	.59	.64	.89
2	90 per cent fine sand, 10 per cent silt and clay.....	.97	1.10	1.33	1.59
2	80 per cent fine, 10 per cent very fine, 10 per cent silt and clay.....	.93	1.07	1.37	1.72
2	90 per cent fine sand, 10 per cent fine limestone soil.....	.72	.85	.96	1.27
1	90 per cent fine sand, 10 per cent calcium carbonate.....	.71	.89	1.55	2.05
1	99 per cent fine washed sand, 1 per cent KNO_3 ³	.74	.98	2.88	7.75
1	98 per cent fine washed sand, 2 per cent KNO_3	.75	1.07	3.20	11.69
1	97 per cent fine washed sand, 3 per cent KNO_3	.73	1.03	3.01	13.77
1	98 per cent fine sand, 2 per cent ground decayed wood.....	.87	.99	1.13	1.61
1	96 per cent fine sand, 4 per cent ground decayed wood.....	1.15	1.33	1.64	1.68

¹ To indicate effect of volume and depth on rate of absorption.

² Washed with 5 volumes of distilled water.

³ Potassium nitrate applied in solution, and water evaporated before starting the test.

It should be borne in mind that the ideal temperature conditions were not attained in this test, and, as has been stated, that at no time has complete saturation of the vapor existed, except possibly for short periods during cooling. This ideal has, however, probably been approached more closely than in any previous test, and the long period employed gives us a new insight into the phenomena of absorption.

The following comments on Table 5 may assist in an understanding of these results. The comparative behavior of various soil combinations will not be discussed, as these merely substantiate the observations of others.

1. The amount absorbed by the unwashed fine sand in 382 days is only one-third more than the absorption in 5 days. It is, however, evident that even at the end of the longer period the unwashed sand was not in an atmosphere of saturated vapor, but rather in one whose pressure was quite as much controlled by the presence of soils still absorbing vapor, and particularly by the sample containing the largest amount of potassium nitrate. Assuming that all the moisture absorbed by the last entered into the salt solution, the latter would be a 22 per cent solution and would stand for an osmotic pressure of more than 45 atmospheres. It is therefore not surprising to find that a soil which contains not over 20 parts per million of soluble matter should make little gain in this atmosphere.

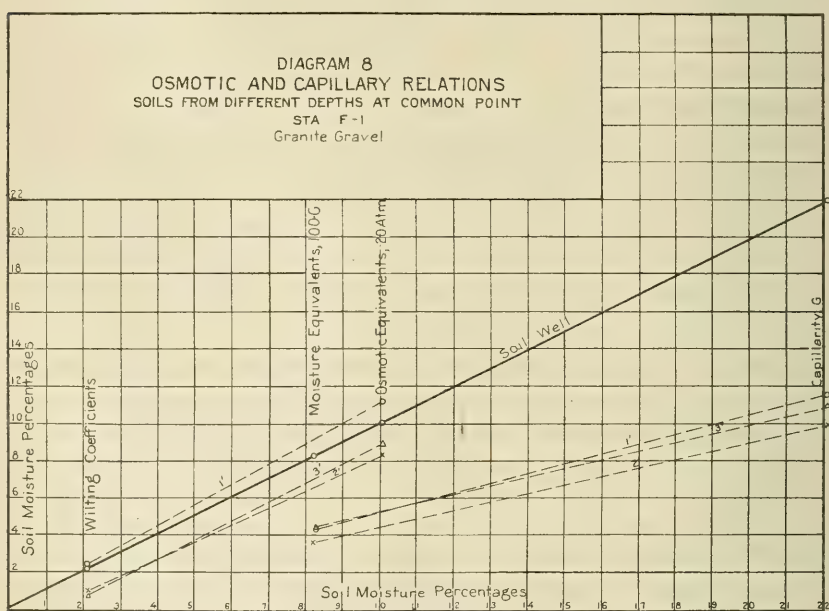
2. On the other hand, the amount absorbed by the fine sand in 382 days is just about equal to the wilting coefficient for this sand, as nearly as can be estimated from a test on the original soil, which contained about equal proportions of material finer and coarser than the fine sand.

3. The continued and relatively large absorption, especially by the soils containing active salts, might be ascribed to the low temperatures under which the test was conducted. It is believed, however, that the evidence of a condition slowly approaching saturation vapor pressure, and never quite up to it, is convincing, and that this explains not only the present results but nearly all the phenomena that have been reported in a similar connection.

A number of other tests somewhat similar to the above were made during 1918, but for short periods only. Several attempts were made to compare the osmotic pressures of soil samples in their natural moisture conditions, by placing the fresh samples under a single bell jar without a control solution, to note whether the samples gained or lost moisture in the common atmosphere. While these gains or losses indicated the relative dryness of the several samples, the tests were not continued long enough to produce any results of value. It was found that a period of two or three weeks was inadequate to bring about equilibrium between the many samples, whose

average weight was about 100 grams. Especially was it noted that surface samples which were nearly air-dry when taken absorbed very little moisture in these short periods.

Finally, from November 28, 1918, to March 29, 1919, a test was made involving samples from nearly all of the regular soil-sampling points at the Fremont Experiment Station, as well as a miscellaneous lot exemplifying various peculiar characters. Two bell jars were employed, a small dish of sodium hydrate solution being placed in each. At the end of the four-month period these solutions had not absorbed vapor to quite the same extent in the two jars, and in neither case was the total absorption equal to the losses from all of the soils. However, for practical purposes the two containers were



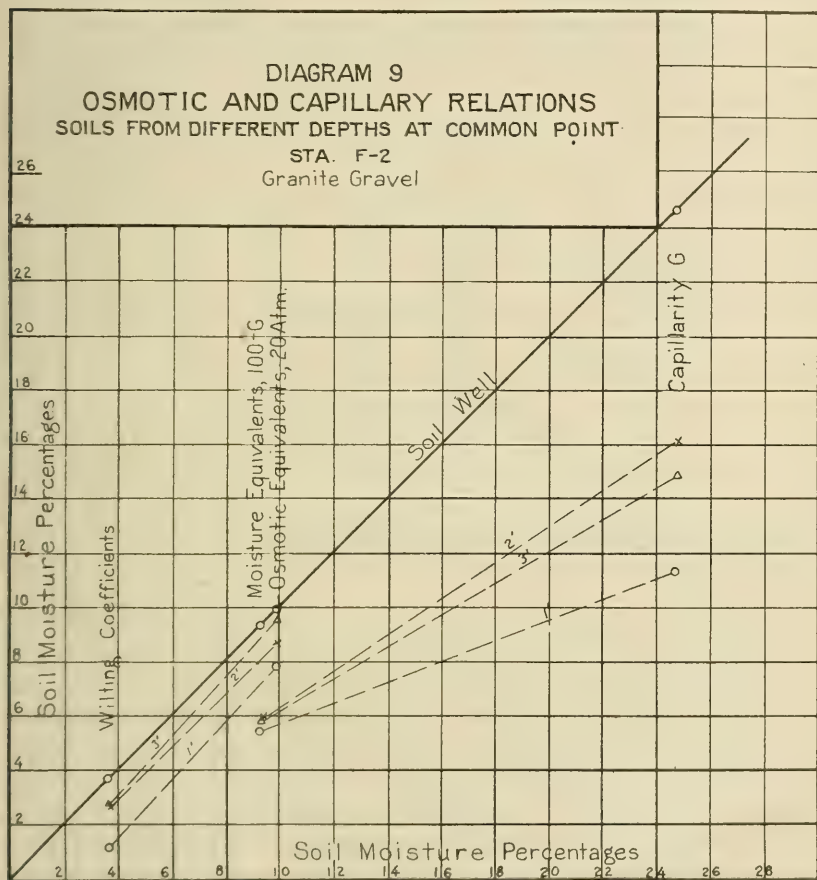
in equilibrium with each other, the osmotic pressures of the solutions being 21.5 and 20.2 atmospheres, respectively.

At the outset each sample of soil was given 10 per cent of moisture above its air-dry weight, so that the moisture was available in liquid form and the various soils were not radically unlike in their initial conditions. While it is not certain that the time allowed was sufficient to establish equilibrium, it is to be noted that the changes in moisture content varied from losses of about 3 per cent to gains of fractional percentages and, in one case, where there was much raw humus, a gain of 15 per cent.

The results, as shown in small part in Table 6 and diagrams 8, 9, and 10, are very elucidating. These diagrams are prepared some-

what in the manner suggested for interpreting the moisture data for soil wells and illustrated in diagram 3.

It will be noted on examining these diagrams, each of which represents the soils from various depths at a single point, that in each group of soils of common origin the lines drawn to connect the capillary moisture and moisture equivalent for each sample tend to converge toward the axis of the system of coordinates and give the



suggestion that in any such group of samples these two measures will vary proportionately. On the contrary, there is a decided tendency toward parallelism in the lines connecting, for each soil, the wilting coefficient and the moisture content at the point of osmotic equilibrium established approximately by this particular test. If, for example, the last-mentioned moisture contents, which may be termed the "osmotic equivalents," be taken to correspond in every case to 20 atmospheres osmotic pressure, and if these be represented

by M' , and the excess over wilting coefficient by K , then in these diagrams the condition is represented by

$$M' = WC + K$$

rather than

$$M' = WC \times K,$$

since it is readily seen that the osmotic equivalents are not proportionate to the coefficients.

TABLE 6.—*Osmotic equivalent of soils, in presence of solution at 20 atmospheres, after four months exposure and other related properties.*

Station.	Depth.	Capillary moisture.	Moisture equivalent, 100-G.	Wilting coefficient.	Osmotic equivalent.	Excess over wilting coefficient.	Change in moisture during transfer.
	<i>Fect.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Grams.</i>
I-1.....	1.....	11.64	4.29	2.31	11.19	8.88	+0.01
	2.....	10.00	3.60	.93	8.7	7.34	-2.39
	3.....	10.96	4.34	.76	8.92	8.16	-2.35
	Well sand.....	22.08	8.25	2.13	10.06	7.93	-0.72
	Avg. of 3.....					8.13	-1.58
F-2.....	1.....	11.34	5.41	1.16	7.84	6.68	-2.62
	2.....	16.08	5.91	2.63	8.69	6.06	-2.20
	3.....	14.84	5.86	2.67	9.58	6.91	-1.67
	Well sand.....	24.70	9.29	3.67	9.87	6.20	-1.24
	Avg. of 3.....					6.55	-2.16
F-11.....	1.....	23.53	13.45	4.72	11.06	6.34	-1.90
	2.....	24.00	16.25	3.65	10.72	7.07	-1.80
	3.....	18.86	11.62	2.99	10.24	7.25	-2.11
	Well sand.....	21.61	6.67	.76	9.90	9.14	-1.29
	Avg. of 3.....					6.89	-1.94

¹ A average of 4 samples taken from each well, representing the surface and depths of 1, 2, and 3 feet, so that mean value should be equivalent to that of soil as placed in the well.

² Approximate. Test made on coarse sandy soil from depth of 4 feet, most nearly approaching the quality of sand used in the well.

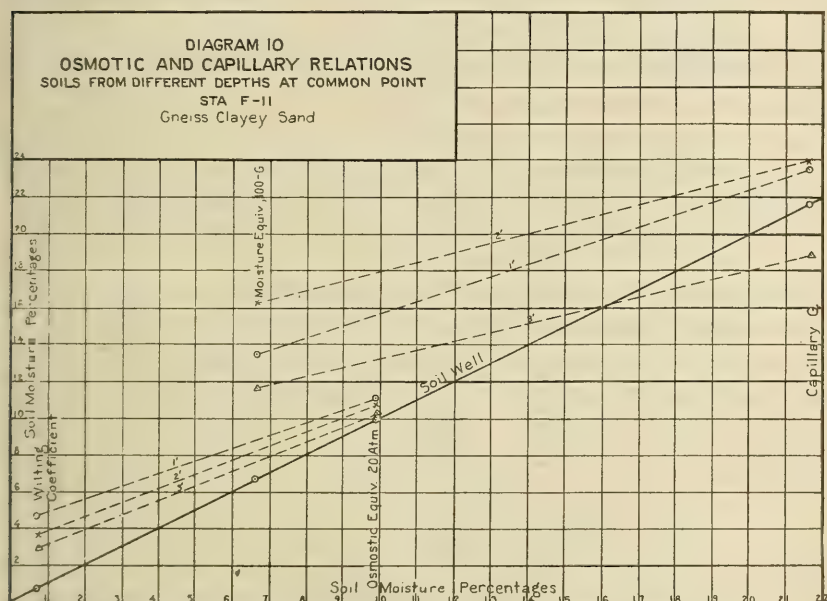
Table 6 shows that K varies as between different groups of samples from different sources, but that within a group of similar origin K is essentially a constant. Thus, it has an average value of 8.13 per cent for one group, 6.55 per cent for another, and 6.89 per cent for the third, and this value seems not to have any constant relation to the change which occurred in the samples during their period of exposure, so that it may be accepted as representing something near a final condition. In one sample representing a limestone soil, K is found to be 17.12—15.33 per cent, or 1.79 per cent. In another soil of lava origin, containing less of silt and clay, but a considerable amount of sodium bicarbonate, K is found to be 12.23—4.44 per cent, or 7.79 per cent.

These findings compel the following conclusions:

1. The wilting coefficient of a given soil is probably dependent both on the solutes present and upon the colloids capable of adsorbing both the solutes and the water, but more particularly upon the latter; since only very rarely will the solutes be so abundant as to create an excessively strong solution before the disappearance of the free water.

2. The osmotic equivalent of the soil is almost wholly dependent upon the solutes present, and among soils of one general type, in which the ingredients are conducive to the creation of solutes at a definite rate, and their free transfer from one point to another, a given osmotic equivalent represents a fairly constant amount of free water plus a variable amount of unfree water, depending on the quantity of clay, humus, etc., in each sample.

3. In such a group of related soils the wilting coefficients may have some fairly constant relation to the capillary moistures or moisture equivalents, because both measures are affected by the water-holding power of the colloids in large part; but a capillary measure



of the condition of the soil water is not alone a safe criterion as to its osmotic condition or availability at points considerably above the wilting coefficient.

It is believed that these conclusions are essentially in accord with those of Bouyoucos (106) and Hoagland (127), as derived from their study of freezing points and osmotic pressures. Probably this conception of the factor affecting availability is of greatest value in explaining the poor growing conditions of undrained soils and the great preference of trees for those which are well drained. It is also of importance in indicating that soils of closely related origin may be compared, as to their current conditions, on the basis of the amount of free or available water in each. This proposition, it will be remembered, the writers were unable to accept with reference to soils of unrelated origins, which gave rise to the need for this whole investigation.

Computing the coefficient of availability.

In computing the coefficient of availability of the moisture at a given part of a tree or other plant, allowance must be made, as has been said, not only for the osmotic pressures at work in the plant and soil, but for the distance through which these must operate, and the effect of gravity on the balance between the two forces. As previously suggested, let

P = osmotic pressure in the plant,

P' = opposing pressure in the soil water;

$L = h$ = height of plant in centimeters at point where P is determined,

G = weight of the column of water to be lifted, in atmospheres, or equal to $h \times 0.00097$ atmosphere.

AA , representing the coefficient of availability, is equal to

$$\frac{P - P' - G}{h}$$

It may then be assumed that the foliage of the tree, at a height of 30 meters above the ground, has been determined by its freezing-point depression to possess an osmotic pressure (P) of 25 atmospheres.

A more complicated case may also be considered. A soil, previously tested, is found to possess an osmotic pressure of 25 atmospheres at 4 per cent moisture content and of 5 atmospheres at 20 per cent moisture content, the former being appreciably above the wilting coefficient. This soil is found to be currently at 6 per cent moisture content. Its osmotic pressure P' may then be computed as

$$25 - 2 \left(\frac{25 - 5}{20 - 4} \right) = 22.5 \text{ atmospheres.}$$

The formula for this case then reads

$$AA = \frac{25 - 22.5 - 3000(0.00097)}{3000} = -\frac{0.41}{3000} = -0.000137$$

The coefficient of availability being a negative quantity of any magnitude, it is evident that the part of the tree which has been examined can not obtain water from the soil unless (1) the moisture content of the soil is increased, or (2) the foliage may withstand further drying and the creation of a higher pressure, without injury. Under the conditions stated as to the wilting coefficient of this soil, it is still probable that the part of the tree examined may obtain water when it attains a drier state.

In the examination of a tree branch of appreciable length, it may be necessary and desirable to make an additional allowance in h for the horizontal distance, as well as the distance from the ground. This addition, however, would not apply to the calculation of G .

OTHER SOIL PROPERTIES TO BE STUDIED.

ACIDITY AND ALKALINITY.

While neither extreme acidity or alkalinity is often encountered in forest soils, because of their usually good drainage, yet the subject is one that should not be overlooked, even though, on account of its relative unimportance, it must be given rather scant space. Unfortunately because of deficiencies in chemistry itself and a lack of proper understanding of the method by which the activity of acids in the soil might be measured, reliable results in such measurements bearing on problems of plant distribution are only just beginning to appear; for this reason, it is unsafe to say that the concentration of acids in the soil either is or is not an ecological problem distinct from the moisture-supply problems which have just been described. The suggestion of direct toxicity of soluble substances in the soil is frequently encountered, but so far as known no one has shown that toxic effects are not effects produced by the cessation of the water stream. It has also been frequently suggested that active acids or alkalis in the soil combine to withhold from the plant the substances needed for its nutrition. This seems more probable. Skepticism in these matters is designed primarily to indicate that such questions are still open to investigation from more than one angle. The methods for determining acidity and alkalinity in soils will be briefly reviewed, as though these were matters entirely independent of the subject of water supply.

A recent and readily grasped article by Wherry (141) is filled with good suggestions on the vexed question of measuring the acidity of soils, and should be read by everyone who intends to go further with this discussion. Among his suggestions, an outline given by him to cover the various methods of acidity measurement will be followed, with some elaboration, also bringing up at appropriate points the corresponding methods applicable to the determination of alkalinity. It should, perhaps, be explained that the term "alkalinity" is here used in its chemical sense, and not with the broader meaning, sometimes permitted, of total soluble salts.

1. A salt solution is added to the soil. For this purpose there have been used sodium chloride, potassium chloride and nitrate, calcium chloride, nitrate and acetate, zinc sulphide plus calcium chloride, etc. The quantity of acid in the resulting solution, which represents that originally present in the soil plus a much greater amount produced indirectly by the processes¹⁸ outlined is then determined by titration or other means.

In the appendix to this paper has been given in detail the titration method for acidity following the "extraction" of the acids of

¹⁸ Briefly, replacement of H ions in compounds which would in stable condition show no evidence of the weak acids present.

the soil by potassium nitrate solution, a method which has been much used and debated, but which should probably from now on be considered only for its historical interest. It has many times been found that this method produces appreciable acidity in soils which at the same time evidence alkalinity.

2. No salt solution, but some pure water, is added to the soil.

(a) The mixture is titrated with lime water, using either an indicator or observation of the freezing point to determine the end point. This gives the amount of lime needed to neutralize the acid originally present in the soil plus that produced indirectly by the action of lime (which is likely to differ from that produced by a neutral salt solution) as well as the amount of lime required to satisfy the absorptive power of the soil colloids for calcium ion under the given conditions.

The determination of the end point in such a water mixture by the freezing-point method is the method described by Bouyoucos (108), and is based on the fact that as long as the CaOH added is combining with a free acid or an acid salt (which is up to the point of neutrality), the solution will contain fewer and fewer ions, and consequently will have a higher and higher freezing point. When the CaOH molecules begin to remain in solution, however, there is an immediate change in the opposite direction. This method appears to have considerable value, though not wholly a measure of the free acids. Likewise, when the reaction of the solution has been shown not to be acid, through an immediate lowering of the freezing point on adding CaOH, it would seem that the normal freezing-point depression was a measure of the alkalinity.

(b) The mixture is filtered and the filtrate titrated with standard alkali. This gives the quantity of acid present in the soil.

By titration with KHSO_4 solution, the filtrate may likewise be tested for alkalinity, the method being described in the appendix. It is perhaps desirable to bring out here, however, since both of these methods may be used, that the commonly used indicator, phenolphthalein, does not indicate neutrality, but a specific alkalinity of 30. Wherry suggests the use of litmus or brom-thymol to detect complete neutrality.

(c) *The hydrogen-ion concentration or specific acidity (or alkalinity) is determined—*

- a. By catalysis of an ester.
- b. By measurement of the potential due to hydrogen-ion with the potentiometer.
- c. By observation of color changes of indicators whose relations to hydrogen-ion concentration are known.

This last-named method is that which Wherry then describes in detail. It consists primarily of the use of six indicators in various

combinations, such that variations between a specific acidity of 3,000 and a corresponding "superalkalinity" may be detected with not too great refinement, yet probably with all the precision necessary in studying the distribution of plants. These extremes correspond, respectively, to hydrogen-ion concentrations of $P_H=3.5$ and $P_H=10.5$.

For the most precise determinations of the degree of alkalinity or acidity the potentiometer is undoubtedly the last word. A number of such instruments are on the market and should require practically no adaptation for the treatment of soil extracts. No reason appears why they might not be readily used in the field. Apparently the apparatus devised by Briggs (111) for determining the "soluble salt content of soils" was of very similar nature, though its relation to hydrogen-ions was probably little understood at the time.

THE MECHANICAL ANALYSIS OF SOILS.

A mechanical analysis of any soil which is being studied extensively is probably worth while if only to give a convenient and approximately correct name for the soil. Thus may be avoided the error of speaking of a soil as a "clay" when, in fact, it contains 80 per cent silt and only a very little clay, or perhaps even a large component of very fine sand and small amounts of the finer materials which make it as stiff as clay. With accumulated analyses of soils, too, comparison will show whether the mechanical analysis of two are very similar, approximately what water-holding capacity a new soil may have, what wilting coefficient, etc. However, in this calculation the humus plays a very important part and its effect is difficult to estimate.

The method of mechanical analysis which may be considered standard has been recently described by Fletcher and Bryan (120). It employs a number of sieves, with perforations of successively smaller size, which separate the particles of various sizes but allow the very fine sand, silt, and clay to pass through. These three grades are then separated in water under the action of gravity.

The standard soil grades recognized by the Bureau of Soils, United States Department of Agriculture, are indicated by the following table of diameters (Table 7), which also indicates the diameters of the circular perforations in the standard sieves. Opposite these values have been set the approximately corresponding sizes of screens which are adapted for handling larger samples in the study of forest soils, under what may be called the "English" rather than the metric system of classification.

TABLE 7.

Class.	Metric. (Diameters of sieve perforations.)	English. (Number of openings per inch.)
	<i>Millimeters.</i>	
Rocks.....	Over 2.....	Less than 4.
Coarse gravel.....	2.00 to 1.00.....	4 to 10.
Fine gravel.....	1.00 to 0.50.....	10 to 20.
Coarse sand.....	0.50 to 0.25.....	20 to 40.
Medium sand.....	0.25 to 0.10.....	40 to 60.
Fine sand.....	0.10 to 0.05 (settles in test tube in 30 seconds)	60 to 100.
Very fine sand.....	0.05 to .005 (settles in centrifuge in 5 minutes at 800 revolutions per minute.)	Over 100 (settles in bottle in 30 seconds).
Silt.....	.005 to 0000 (does not settle in centrifuge; measured by deduction.)	Same as metric.
Clay.....		Turbid water evaporated and weighed.

The following procedure is suggested as the result of a good deal of experience in treating forest soils:

1. If the soil to be sampled contains a great deal of rock, say over 25 per cent by volume, and of large size, it is desirable to determine the rock percentage by sifting a considerable quantity of the material through a screen having four meshes to the inch. This should be done only when the material is air-dry, and should be accompanied by much beating and brushing to remove the fine material from the rock surfaces. After the process, a sample of about 100 grams of the finer material may be taken. If rocks are few and small, it is better to sample and wash them with the other material, separating them when dry from the coarse gravel on the 2-millimeter or 10-mesh sieve.

2. The sample is placed in a wide-mouth 8-ounce bottle, which is then nearly filled with clean tap water, stoppered, and placed on the shaking machine, or attached to a pulley which is turning at the rate of about 100 revolutions per minute. The amount of shaking necessary will vary from two to eight hours with different soils, but should always be sufficient to break down every lump of whatever size. If the soil lacks gravel for its own pulverizing, place two or three round pebbles in the bottle.

3. The lumps thoroughly broken down, the contents of the bottle are placed on the coarsest screen, with the finer sieves in succession below it, and the whole nest standing over a can of 1 or 2 gallons capacity. The material is washed down through each screen by a tiny stream of water, until all silt and clay have been removed; that is, until the water comes through perfectly clear. The nest of sieves may then be placed in the oven to dry, after which the separation of the sands is readily accomplished by a little jarring of each sieve; the material held on each is weighed promptly, before it can take up moisture from the air.

4. The very fine sand which passes the sieves after drying is placed in the washing bottle. The water from the washing of the material several hours earlier may now be decanted off into a meas-

uring vessel, leaving the very fine sand in the can, some silt and clay, and a little water. This material is also transferred to the washing bottle. As the first measure of liquid in the bottle will be very rich in silt and clay at least one minute should be allowed for the very fine sand to settle. After this time the silt and clay are partially decanted into the measuring vessel. More water is added to the bottle and is thoroughly stirred. With each successive washing the time is reduced, so that as the water becomes nearly clear the sand is allowed just 30 seconds to settle through a 4-inch column of water. It will be noted that the settling is somewhat slower if the water is extremely cold.

5. All the very fine sand is now in the wash bottle, in which it may be dried and weighed, and all of the silt and clay, with a considerable volume of water, in the measuring vessel. It will be economical to obtain the weights of the silt and clay by merely sampling this large volume after thorough stirring. Perhaps 100 cubic centimeters may be drawn off for centrifuging from a total volume of 2 liters. The amount and fineness of the material thrown down in the centrifuge will depend on the time of centrifuging and the speed of the machine. These should be adjusted after repeated trial and examinations of the suspended particles under the microscope. (See Briggs, Martin, and Pearce (117).) However, as the standards for "clay," "silt," etc., are purely arbitrary any investigator may, for his particular purposes, adopt his own, as by deciding on a period of centrifuging which will in every case clear the water of particles of visible size.

The centrifuging completed, the clay water is decanted off into one evaporating dish, and the silt in each tube is washed out with a fine jet of water into another. These are dried in the oven. Care should be used to avoid weighing either the clean dishes or dishes containing this fine material when the general humidity is very high. The amount of silt and clay in the evaporators having been determined, the total amount for the whole sample is readily calculated.

6. The quantities have now been determined in nine grades, and the percentage of the whole which each grade represents may be readily computed. The several percentages may be entered on the form for "Summary of Physical and Chemical Properties of Soil" (p. 134).

It will be noted in the following key that no grade coarser than coarse sand is mentioned. In analyses made by the Bureau of Soils it is customary to pass the material through the 2-millimeter sieve before sampling and to base all calculation on the total weight of this "fine earth"; that is, material not coarser than fine gravel. In forest soils coarser material is too commonly met with to be ignored, and its importance from certain points of view may be as great as

that of the soil proper. It is believed, however, to be desirable to describe the soil in such manner as to denote separately the presence of a coarse matrix and a finer soil occupying its interstices. Thus if rocks or gravel formed more than 10 per cent of the mass we might speak of the soil as a "rocky medium sand" or a "gravelly loam." In this event the fine gravel and finer material should be considered as constituting 100 per cent when using the following key:

CLASSIFICATION OF SOILS ON MECHANICAL ANALYSIS.

Soils containing — 20 silt and clay:

Coarse sand	25+ very coarse sand and coarse sand and less than 50 any other grade.
Sand	25+ very coarse sand, coarse and medium sand, and less than 50 fine sand.
Fine sand	50+ fine sand, or — 25 very coarse sand, coarse and medium sand.
Very fine sand	50+ very fine sand.

Soils containing 20 to 50 silt and clay:

Sandy loam	25+ very coarse sand, coarse and medium sand.
Fine sandy loam	50+ fine sand or — 25 very coarse sand, coarse and medium sand.
Sandy clay	— 20 silt.

Soils containing 50+ silt and clay:

Loam	— 20 clay, — 50 silt.
Silt loam	— 20 clay, 50+ silt.
Clay loam	20 to 30 clay, — 50 silt.
Silty clay loam	20 to 30 clay, 50+ silt.
Clay	30+ clay.

THE DETERMINATION OF HUMUS.

The amount of humus in the soil, which plays an important part in the water relations and may also be an important source of nutrients, may be determined in two general ways:

1. By ignition, taking no account of the degree of decomposition of the organic matter, and always involving some error through the evaporation of water which may exist in several forms in oven-dried soils.

2. By extraction of the humified portion of the organic matter with ammonia, and its subsequent ignition.

It should be realized that these two methods produce entirely different results and, in fact, they have distinct purposes. On the one hand, the total organic matter is of interest because of its bearing on the water-holding properties of the soil, and in this connection the total loss on ignition is probably as expressive as any other measure, though in soils containing large quantities of carbonates some correction must be made for their breakdown. It is, however, a

misnomer to call this a "humus determination." On the other hand, the amount of humified material is important as a possible source of nitrogen, it being, according to Hilgard (125), "wholly uncertain to what extent the unhumified material will ultimately become humus, from the nitrification of which plants are presumed to chiefly derive their nitrogen."

Loss on ignition.

Loss on ignition, as has been said, may be of interest in connection with water-holding properties. It is readily determined by placing approximately 100 grams of the soil in a shallow earthen or platinum dish, in which it will first be oven-dried and weighed and then heated to red heat in a gasoline or electric oven, with a moderate current of air passing over it. Providing lumps have been broken down at the outset, the oxidation may usually be completed in an hour. After this the sample is again weighed, the ignition loss is calculated, and the percentage of loss is based on the oven-dry weight of the sample.

In the case of soils containing considerable lime or magnesium carbonate, the error through the breaking down of these on ignition may be largely eliminated by a preliminary treatment with dilute hydrochloric acid, as in the humus extraction method.

The ammonia-soluble humus.

The ammonia-soluble humus, or *matière noire* of Grandeau (122), is the aim of all of the more recent methods of extraction. Lime and magnesia are first removed by washing the soil with dilute hydrochloric acid. Grandeau mixed the washed soil with coarse sand and placed it in a funnel at the bottom of which were fragments of glass or porcelain. The whole mass was then moistened with dilute ammonia and allowed to digest for three or four hours, after which the solution was washed through with water or water containing a little ammonia. The filtrate was then evaporated to dryness, weighed, ignited in a platinum dish, and weighed again. The loss on ignition is the measure of the extractable humus. The residue is termed humus ash.

Hilgard¹⁹ modified the Grandeau method by placing the soil in a paper filter, covering it with a disk of filter paper, and here performing both the acid washing and the ammonical extraction. The latter is accomplished with 4 per cent ammonia water until the filtrate comes through colorless.

Others have attempted to improve on Hilgard's method in order to expedite the process; but, as shown by Alway, Files, and Pinckney (101), they have introduced serious error through including in the ammoniacal extract considerable amounts of colloidal clay which, on

¹⁹ In Bulletin 38, Bureau of Chemistry, United States Department of Agriculture, 1893.

ignition, suffers a loss of water. The experience of the writers indicates that the sand filter devised by Grandeau, with also the paper filter used by Hilgard, will come nearest holding the colloids in the soil. Such as are likely to escape will have passed the filter by the time the acid treatment is complete. In the case of the coarser forest soils the addition of sand is wholly unnecessary.

Alway suggests the recording of the humus ash percentage as well as the humus as a means of detecting the errors which commonly enter into this determination.

CAPILLARY CONDUCTIVITY.

As has been frequently pointed out in the discussion of the moisture problems, the rate at which a plant is able to obtain water from the soil particles with which the roots are in actual contact may have an important bearing on the wilting coefficient for the whole soil mass, and may, in turn, depend largely on the facility with which the moisture travels from one soil particle to another when there is unequal distribution. Thus, a clean sand is generally understood to have the highest conductivity (whether because of the close contact between the particles or because of the clearness of the spaces between the larger particles, is not known), while clay in the soil seems to impede this movement, probably because of absorption, and humus appears to retard the movement, possibly by breaking the contacts between the mineral particles.

The whole subject of capillary conductivity appears to have been thrown into confusion in recent years by practical findings, especially in connection with the study of moisture supplies in the arid farming regions of the West. In brief, it has been found that in certain localities the soil is never moistened to a greater depth than, say, 10 feet, by precipitation; that the moisture which goes beyond the depth of ordinary crop roots is never brought toward the surface by capillary action, and hence is lost for practical purposes; that fallowing with the object of storing moisture in the deep soil is therefore useless.

Buckingham (116) and McLaughlin (132) have apparently made the most exhaustive studies of the movement of soil moisture; and it may be said that these investigations confirm the practical conclusion that when the mean moisture content is very low and the difference in moisture between two points is slight, the rate of movement from the moister to the drier point is negligible. These, of course, are the conditions to be dealt with as the wilting coefficient is approached, and it is somewhat relevant to remark that there is no evidence against the ordinary conception of capillary movement when the amount of moisture in the soil is considerable. It is true, however, that this movement is very slow upward—that is, against the force of gravity.

Considering only that which is particularly relevant to the problem, it was found by Buckingham that considerably different types of soil show about the same capillary flow under the same conditions. A moist and a dry layer of soil were, in these experiments, placed one above the other in direct contact. The amount transferred from the moister to the drier soil in a given time was found to depend almost wholly on their original difference in moisture content; furthermore, the greater part of this transfer was accomplished in a very short time.

A great many methods have been devised for showing the rate of movement of water in soils; but none of these, so far as known, is readily standardized or will produce closely comparable results on duplication with the same soil. This is because the granulation of the soil has an important influence on the capillary forces set up. In view of this difficulty, no procedure can be suggested which is more likely to produce reliable comparative data than the following:

After the completion of the moisture equivalent determination on the centrifugal machine, all water having been extracted which is subject to the force employed (whether this be 100 gravity or 3,000 gravity), and the soil being then in a state of compactness which is somewhat close to a standard, add to the unit volume of soil a small standard amount of water, say 10 cubic centimeters; as soon as this has been absorbed in the surface centrifuge again for short periods until the amount added has been extracted, determining the time for this unit process. This should be a measure of the resistance offered by the soil to the passage of a unit amount of water through a unit distance (the distance may be somewhat variable, but correction may be made directly).

It would be unwise to leave this very open subject without reference to the possibilities of the electrical conductivity method; for, as Buckingham (116) has shown, there is a close correlation between the conditions affecting electrical conductivity and those affecting water conductivity in a given soil. It would seem that there is also a chance for correlation between heat conductivity and water conductivity.

CHEMICAL ANALYSIS FOR NUTRIENTS.

It may be said that almost nothing is known as to the quantitative requirements of most plants for the nutrient materials obtainable from the soil with the soil water, and little enough as to the elements which in greater or less quantity are essential for growth. The lack of knowledge with respect to trees is especially glaring,²⁰ little atten-

²⁰ The writers do not consider the evidence obtained by the examination of leaf ash and other similarly crude methods, even as convincing evidence of qualitative requirements.

tion having been paid to the subject because of the almost universal belief that the requirements of trees are satisfied by almost any soil. That this is probably true of such trees as the pines is evidenced by their adherence to light, sandy soils. In fact, rather low requirements may be assumed for all of the evergreens on theoretical grounds, because of the fact that the green, functioning parts are of long life and the main product, cellulose, is a purely organic compound.

Ecologically speaking, evidence of any direct part played by soil fertility in the distribution of species, and especially of forest trees, is rarely found. This may be partly explained by the fact that forest soils are usually young and potentially fertile, so that other characteristics, especially water-holding capacity, come into greater prominence. Much careful work must be done, however, to determine where and when soil fertility becomes an important ecological factor.

Much difference of opinion exists as to how the fertility of the soil should be measured. There is potential fertility in practically all of the soil mass except the silicon, and actual available fertility only in those substances which are currently in solution with the soil water. As has been pointed out, notably by Hoagland(127), the quantity of all substances in solution varies not only with the drain upon these substances by plants, but with the quantity of the soil water. For practical purposes these substances may be said to be soluble only to a limited extent.

The ordinary complete quantitative analysis of a soil involves the treatment of all of the mass susceptible to chemical action, with a view to discerning potential fertility. In some young soils, especially if formed in situ, these potentialities may be arrived at by the experienced person through examination of the mother rock. Where there is any question, however, the ordinary investigator, because of the great amount of equipment and technique involved, should refer samples for analysis to some well-equipped laboratory, such as that of the Bureau of Soils in Washington. Four or five pounds of the soil are required for complete analysis. The samples should be thoroughly air-dried when taken from the ground, freed of rocks, and shipped either in jars or in heavy canvas sacks from which the fine material will not be lost.

To obtain a measure of the total soluble salts readily available in the soil solution, where the chemical make-up of the soil is generally known, or may be assumed to be adequate for all needs, extraction of the solutes by leaching may be employed. For comparative purposes, the amount which may be extracted with five volumes of distilled water (1 liter for 200 grams of soil) will serve as well as a more thorough extraction. The soil is placed on a

paper filter, in a 6-inch funnel, and the water is poured on to it, a few cubic centimeters at a time, through a period of 24 hours. Before the soil has thoroughly settled, some clay is likely to pass through the filter. This is eliminated by pouring on to the soil a second time the first 100 cubic centimeters of water which passes through. When all of the water has drained out, the solution may be partly boiled away and allowed to cool, when the suspended matter will largely flocculate and may be removed by a second filtering. The clear solution is then evaporated in a weighed porcelain dish. Solutes varying in amount from 20 to 1,500 parts per million of the soil weight are ordinarily found in such extracts.

This subject has been investigated in great detail by King (129).

For the purpose of ecology, qualitative analyses showing the presence in some quantity of the elements and compounds known to be essential, may often be all the chemical evidence that is required to throw the burden upon some other environmental condition. Following Osborn (135), who has rather recently given a summary of the evidence on this subject, the investigator may look for:

1. Nitrogen (in the form of nitrates), as an essential constituent of protoplasm, required in large quantities when the proteins are being produced, as in seed formation. Nitrogen is itself practically useless without nitrifying agencies in the soil, so that the presence of humus is not absolute proof of the abundance of nitrates. Nitrogen in certain forms may also, as shown by Schreiner and Skinner (138), inhibit plant growth. This is a subject of great complexity.

2. Phosphorus, as an essential of the nuclei of cells.

3. Iron, as an essential of protoplasm, and playing an important part in the formation of chlorophyll. A lack of iron in available form is quickly shown in yellowing or "chlorosis" of foliage.

4. Magnesium, as a constituent of the chloroplasts.

5. Sulphur, required for forming proteins.

6. Potassium, probably as a regulator of life phenomena through chemical reactions.

7. Chlorine, commonly present in plants and probably functioning in metabolism.

It is with a view to detecting the lack of some of these substances that the following simple tests are enumerated, requiring the minimum of laboratory equipment and technical skill.

The sample of air-dried soil which is to be examined should be placed in a glass jar and distilled water added to the amount of five to eight times the volume of the soil. After about five minutes the solution may be used.

One hundred cubic centimeters of the solution may be tested qualitatively for chlorine. For this purpose, to the soil solution

should be added one or two drops of potassium chromate ($K_2Cr_2O_4$) solution and titrated from a dropper by a weak solution of silver nitrate ($AgNO_3$). If chlorine is present it will be precipitated as silver chloride. The test for chlorine can be made also more simply by taking some of the soil solution in a test tube and adding silver nitrate solution.

For tests of the presence of other chemical substances which may be of importance in the life of plants, the following procedure is suggested:

Three hundred cubic centimeters of the soil solution are poured into a porcelain dish and slowly evaporated, the drying being continued almost to red heat in order to burn any organic matter. If the organic matter is not burned up in the porcelain dish containing the dry residue, aqua regia is added and the liquid evaporated to dryness at least twice. The residue is then heated to red heat in order to render the silicic acid insoluble. The soluble residue is dissolved by heating in a weak solution of hydrochloric acid, and the liquid is filtered off from the white amorphous residue of the acid. The filtrate is collected into a graduate and water is added to bring it up to 300 cubic centimeters. Of this the following amounts are taken for further tests:

1. One hundred cubic centimeters for determining the entire amount of Fe_2O_3 (ferric oxide) + P_2O_5 (phosphorus pentoxide) + Al_2O_3 (aluminum oxide) + CaO (calcium oxide) + MgO (magnesium oxide).

The solution is neutralized with sodium carbonate (Na_2CO_3) until some cloudiness appears, then from 5 to 10 cubic centimeters of sodium acetate ($NaC_2H_3O_2$) are added and the solution is heated; the entire amount of ferric oxide and aluminum oxide will be precipitated in the form of basic acetates. These are filtered off. The filtrate is heated and neutralized with ammonia (NH_3) until an alkaline reaction is obtained, then 1 or 2 cubic centimeters of ammonium chloride (NH_4Cl) and ammonium oxalate ($(NH_4)_2(COO)_2$) are added. The calcium is precipitated and is filtered off.

To the filtrate, after it has been cooled off, are added several cubic centimeters of sodium ammonium phosphite (NH_4NaHPO_3), and it is left to stand for several hours. If magnesium is present it will be precipitated.

2. One hundred cubic centimeters for determining SO_3 (sulphur trioxide).

For this determination the 100 cubic centimeters are heated and to the solution are added several drops of barium chloride ($BaCl_2$). If SO_3 is present, it should precipitate in the form of barium sulphate ($BaSO_4$). If it is not precipitated at once, the solution to

which barium chloride has been added is left to stand for several hours.

3. One hundred cubic centimeters for determining P_2O_5 (phosphorus pentoxide).

In order to determine the presence of phosphorus pentoxide (P_2O_5), 100 cubic centimeters of the solution is neutralized with ammonia until an odor is perceived, the solution is made acid by the addition of weak nitric acid (HNO_3), and to such acid solution there is added from 10 to 15 cubic centimeters of molybdic acid (H_2MoO_4).

A qualitative test for ferric oxide can be made in the water solution of the soil by hydrochloric acid. Some hydrochloric acid is added, together with several drops of potassium sulpho cyanide ($KSCN$). A pink, or often bright red, color will indicate the presence of ferric oxide in the solution. When the soil is rich in ferrous oxides, their presence can be readily ascertained by dropping directly upon the soil some of the potassium ferricyanide ($K_3Fe(CN)_6$) solution which with the ferrous oxides gives a blue color.

The form for the "Summary of Physical and Chemical Properties of Soil" is provided with a number of blank spaces in which the results of qualitative or quantitative tests for various salts may be entered.

SUMMARY OF SOILS DISCUSSION.

The preceding discussion has attempted to bring out the theoretical considerations which make the study of soils very important in forestry, from the standpoint of initiation of seedlings, later competition between individuals and species, and the rate and ultimate limit of height growth on any particular site. In the main all other soil conditions have been considered in their bearing on the supply of soil moisture. In view of the length of the discussions, it would appear desirable to repeat the salient points, as follows:

1. It is believed that from every ecological aspect the important soil condition is the availability of the soil moisture.

2. Plans for the study of this soil condition have been based on the assumption that the relation between the plant and the soil in which it grows can best be demonstrated if, at any time, the status of either may be expressed in terms of osmotic pressures.

3. The generally coarse character of forest soils, and the presence of rocks which are as characteristic as any other part of the soil and can not properly be eliminated, give rise to the need for special methods of examining forest soils, and particularly for methods adapted to larger samples of the soil than have commonly been used in agricultural investigations.

4. The total moisture of the soil, while not directly making possible the comparison of sites, if there be any variation in soil composition, must be had for most of the indirect methods of comparison; and in forest studies it must be determined periodically through one or more seasons in order to discover the conditions that are critical. The quantity may sometimes be found through ordinary methods of sampling and drying the soil samples; but often, because of mechanical difficulties, and to insure greater physical uniformity in the samples from time to time, it is desirable to have "wells" of prepared soil from which successive samples will be taken.

5. If it seems desirable to compute the moisture of the natural soil from that found in a soil well, this may be done, at least approximately, by comparison of the capillarities, moisture equivalents, and wilting coefficients of well soil and natural soil, respectively. It seems probable, however, that up to a high moisture content osmotic equilibrium is more likely than capillary equilibrium between the well and the natural soil, so that if the moisture of the former may be expressed in terms of osmotic pressures, it is unnecessary to compute the moisture of the soil.

6. For any study of the critical situations in soil moisture, either for seedlings or for older trees, it is necessary to know the wilting coefficient of each soil under consideration. The moisture content at which a plant may wilt, however, varies widely not only according to

physical properties of various soils, but also, for any given soil, according to the manner in which the test is conducted, the age and species of the plants employed, and, more important still, according to the atmospheric conditions at a time when the moisture supply is running low. In short, the wilting coefficient is dependent vary largely on the rate at which the plant must obtain water in order to balance losses. As the atmospheric conditions are difficult to control, and practically impossible to reproduce from time to time and place to place, it follows that wilting coefficients are empiric quantities and have no precise value.

7. It is probably very desirable that wilting tests should be continued as a further check upon theory, and for the further establishment of relations between different species and different soils. Relative values for different species and soils, of much value and interest, are to be obtained through simultaneous tests at any given point, and by such comparisons a scale of values either for soils or for species may eventually be built up. There are, however, indirect methods of arriving at the wilting coefficient which are not only desirable for practical purposes, but will add greatly to our understanding of the variations in wilting coefficients due to biological and environmental factors.

8. The study of the freezing of soil water, the study of the acquirement of moisture by soils when exposed to saturated vapor, and even the behavior of the soil water when subjected to an external mechanical force, all point to the fact that water may exist in the soil as a liquid, capable of more or less movement from one soil particle to another, or as a vapor;²¹ that is, as separate water molecules, held in place by the affinity of the solid particles, and thereby prevented from moving. All signs, too, point to the fact that, except possibly in soils of unusual alkalinity or acidity, the soil water is truly nonavailable only when it ceases to function as a liquid. While wilting of plants may often occur with liquid water still available, this is readily accounted for by the slow rate of movement toward the roots, which become a probability, especially in clay and humous soils, whenever the volume of water is not large. Water obviously moves much more readily in coarse than in fine or humous soils; and, as has been mentioned, the rate which may be fatal to a plant depends on the needs of the plant as determined by its losses.

9. While, therefore, no method has yet been devised by which the theoretical and exact wilting coefficient may be directly arrived at, any one of the methods mentioned in the preceding paragraph has its

²¹ It would, perhaps, be more descriptive of the kinetic status to speak of this as "solidified water" and it is not certain that a wide separation of the molecules, as in vapor, is an essential part of the situation.

possibilities as an avenue of approach. Thus, by the freezing-point method the osmotic pressure of the soil solution corresponding to any given moisture content may be determined; and by several trials, the point at which the soil water ceases to behave as a liquid, that is, ceases to show a definite freezing point, may be determined quite closely. This water content is probably the term sought as a standard. The freezing-point method has one serious objection: namely, that it forbids keeping the soil during test in a natural state of compactness, or with a natural arrangement of the soil particles.

The vapor transfer method has also many possibilities. In the ordinary determination of the hygroscopic coefficient the water vapor is probably not entirely saturated; and, in consequence, under certain empiric conditions of the test, there may be obtained in a limited time a limited absorption of vapor by the soil which was air-dry at the outset. The quantity absorbed, so far as the tests go bears a fairly constant relation to the wilting coefficient, the ratio of the two quantities being approximately 2:3. The objection to this method is that the conditions are purely empiric, and the quantity of soil treated is very small.

By exposing soils to water vapor in a vapor-tight chamber, such as a bell jar, and in the presence of a solution of an active salt which represents a given osmotic pressure and vapor pressure, considerable masses of soil may, after a long period, be brought to vapor pressure equilibrium with the solution and with one another. The moisture content of each soil is then the "osmotic equivalent" of the control solution, whose osmotic pressure is readily calculated. The osmotic pressure to exist at the end of the test may be in part controlled by calculations at the outset, and later by changing the control solution. A solution, at the end of the test, representing 50 atmospheres osmotic pressure, for example, might be taken as a standard for establishing osmotic equivalents in lieu of wilting coefficients. The objections to this method are the long time required to complete a test and the absolute need for a constant temperature, or at least for the elimination of rapid changes. The former objection is partly counterbalanced by the number of soils which may be treated simultaneously.

In the moisture-equivalent determination, as so far conducted, the moisture of any soil is submitted to a definite centrifugal force which tends to separate it from the soil. Within the limits of agricultural types of soil, at least, the force of 1,000 gravity employed by Briggs and Shantz (114) appears to leave in the soils amounts of water which bear a nearly constant relation to the respective wilting coefficients. Experiments with a force of 100 gravity have shown wide variations in results with different types of forest soils, indicating that, as humus and clay proportions vary, both strong and weak

capillary tensions are set up, and these do not react in the same way on relatively large and very small quantities of water in the soil. It appears, therefore, as suggested by Free (121), that the effective procedure is the employment of a variable force, sufficient in the case of any particular soil to extract all of the water which is extractable. It seems probable that this quantity would correspond to all of the liquid water capable of moving from one part of the soil to another. The remaining water would probably correspond closely to the "unfree water" of Bouyoucos (106) and what in this bulletin is termed "water vapor," or water whose molecules are too rigidly held by solid substances to have the motility of liquid molecules. While this method is as yet untried and would obviously be more laborious than the present standardized procedure, possibly presenting new mechanical difficulties, it promises so much as a direct and rapid means of determining a physical constant that it deserves serious investigation. In the meantime the 1,000-gravity test should be employed as the basis for comparing the moisture conditions of various soils and in the detailed study of their wilting coefficients.

10. Once the wilting coefficient of a soil has been determined, directly or indirectly, the current moisture condition may be expressed in terms of the percentage of available moisture or the available moisture per unit of soil volume, by subtracting the nonavailable moisture from the whole. The amount of water per unit of volume recommends itself particularly in comparing the conditions of open and dense forest stands, provided that the root extent of the individual tree has been investigated. Without such information, very wrong conceptions of the moisture supplies available to the individual trees in different forest types are likely to be formed.

11. For the purpose of expressing the condition with which any individual plant is coping, particularly the conditions against which a seedling must struggle in times of drought, it is very desirable to reduce the water content of the soil to terms of availability. If it is assumed that the wilting coefficient stands for a definite osmotic pressure in the soil, with which the osmotic pressure in the plant is in equilibrium (this, of course, being only approximately true, as pointed out in paragraph 6, and being further subject to the conditions of the plant, as indicated in the following paragraph), then, when the moisture content is equal to the wilting coefficient, the availability of the soil water is 0.

When the moisture content of the soil is twice as great as the wilting coefficient, about twice the osmotic pressure may be expected in the plant as in the soil, and this should make possible a fairly definite rate of absorption by the plant. The availability at this point may be called 0.50. Similarly, when the moisture content is three times the wilting coefficient, the availability may be expressed as 0.67. It

should be understood that these are arbitrary terms, and that they only express relatively the conditions under which a given plant in a given soil may be obtaining its water from time to time, perhaps a little more clearly than these conditions can be expressed through the percentage of available water.

12. Finally, the plan of expressing the relation between the plant and its moisture supply currently and accurately through the osmotic pressure of each has been conceived. The difference in osmotic pressure in favor of the plant expresses the degree of control of the plant over its water supply; but, since the highest osmotic pressure in the plant is likely to be attained at that point which is farthest from the roots, where also the danger is greatest, it is evident that in considering the availability of water to this point there must be considered the distance through which the differential pressure must operate; or, in other words, the osmotic gradient, say, per centimeter of stem tissue, etc. This gradient will also be affected by gravity. As the coefficient of availability, therefore, a term has been proposed which brings these elements into their proper relations with definite values. Thus,

$$AA = \frac{P - P' - G}{h}$$

a formula which promises to be especially enlightening in studying the phenomena of growth in older trees, as they compete with one another and reach their limits of height for a given site. The value of AA is seen to fluctuate with each change caused by water loss or accretion in the region where P is determined, as well as with gradual changes in the conditions of the soil moisture.

13. The discussion has included other aspects of the soil, which, with the possible exception of nutrition, it is believed should be considered only as indicator aspects; that is, these aspects will only serve to explain the phenomena of soil moisture. They include alkalinity or acidity, humus content, composition (as indicated by the sizes of the soil particles), and the capillary transporting power of the soil.

14. In the study of seedlings during their most critical periods of establishment—this being the period when the character of the plant society is most largely determined—it is believed that the percentage of available moisture within reach of the usually short roots is of primary importance. To determine this with any accuracy will be found difficult on account of the usually heterogeneous character of the soil layer that will be involved. The proper study requires:

(a) Determination of root depth at each examination. It is through this determination that a distinction between species may be made.

(b) Selection of the soil sample at the point of maximum moisture content within the zone reached, which, of course, in the important periods of drought, will usually be the deepest point reached.

(c) Determination of whole moisture of each sample.

(d) Determination of moisture equivalent of each sample, at least as a means for classification of unlike samples.

(e) Retention of samples, with determinations of wilting coefficients on typical classes, probably after the period of field observations. In these determinations it will be well to compare the behaviors of the two or more species involved.

It is believed that, with tiny seedlings, the quantity of water usually required to maintain life is so small that the available volume may be left out of consideration. In other words, the samples may be practically point samples, seeking always the maximum available. Even this painstaking examination of soil moisture, however, may be futile without a record of the conditions conducive to water loss, particularly the temperature conditions at the surface of the soil.

15. Whenever, in a plant society, competition between individuals of the same or different species becomes a factor, the moisture problem is different from that which confronts seedlings. In the forest there may be competition for moisture without keen competition for light, but the two will usually be closely interrelated. In any ordinary situation the keenest competition for moisture occurs near the end of the growing season, when the reserve winter moisture has been exhausted and the current rate of use is in excess of the current accretion. Where this is the case the study of soil moisture may be restricted to a period of two or three months in the late part of the season.

It is evident that, of two individuals on the same site, one may possess an advantage over the other through deeper rooting. It is therefore essential in each site studied to know the extent and depth of the roots of the plants under observation, and to sample the soil for moisture in accordance with a root map.

If it should appear that two individuals in competition have essentially the same moisture supply, then it obviously becomes necessary to determine their respective relations to that supply by examination of their internal conditions as affected by atmospheric conditions, light, etc. It is not sufficient in these circumstances to say that soil moisture is not a factor in the greater success of one than of the other. By measuring the osmotic pressures of the plants it may be found, for example, that the individual which is most exposed to light, wind, and other desiccating influences has a greater control over soil moisture than the near-by individual which is shaded and protected, and which, nevertheless, may die from the effects of

drought while the other thrives. Unless, then, it is desired to deal in generalities, and ascribe to one species certain characters which another does not possess, on the basis of general knowledge or pure assumption, it will be necessary in studying competition to go to the whole length prescribed for the determination of the coefficient of availability.

16. Much the same situation exists with respect to the study of the final character of the forest formation, its height, rate of growth, etc. The critical study of the moisture conditions in relation to ultimate height is of special importance in forestry because ultimate height, in forest management plans, is often taken as a criterion of the quality of the site; that is, its yield possibilities. Are the two things closely related? If the ultimate height is limited by drought conditions which occur only periodically, may not the yield possibilities be considerably greater or less than would be indicated by this measure, depending very much on the total water-holding capacity of the soil, etc.? Obviously such questions as these can be answered only after exhaustive study. This requires the establishment of permanent soil-moisture stations, the determination each year of the critical conditions that exist, and the use of the entire system that has been suggested for arriving at a measure of the true conditions.

SPECIAL EQUIPMENT FOR SOIL MOISTURE AND SOIL QUALITY STUDY.

Soil sieves:

Standard soil sieves. Per set, about-----	\$10.00
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Soil borers:

3-foot soil borer, tube, with hammer-----	9.00
6-foot soil borer, tube, with hammer-----	11.00
6-foot soil borer, auger handle hammer-----	12.00

Soil cans:

Patent seamless, noncorrosive, tin soil cans—

4-ounce can, deep style, per gross-----	3.50
8-ounce can, deep style, per gross-----	4.00

(35 per cent discount on above prices to United States Government.)

Soil sample cans, seamless tin, No. 9178 A—

Capacity, ounces-----	4	8	16
Per dozen-----	\$0.22	\$0.33	\$0.55

Soil sample cans, aluminum, with screw tops—

2½ inches in diameter by 2½ inches high, unnumbered 9183, each-----	.25
---	-----

With can cover numbered. (In ordering, state what numbers are desired.) No. 9183 A, each-----	.30
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Soil sample can, aluminum, with aluminum top. The diameter of these cans is uniform, so that the cover fits the bottom of the can,

Soil cans—Continued.

making it possible to keep can and cover together while the can is open—

Number	1	2	3
Diameter, inches	2	2½	3½
Height, inches	$\frac{7}{8}$	1¾	2
Each	\$0.11	\$0.15	\$0.20

With can and cover numbered. (In ordering, state what numbers are desired.)

No. 9184 A, each	\$0.16	\$0.20	\$0.25
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Aluminum soil cans, 2½ by 2½ inches, with screw tops—

Lightweight, per hundred	\$38.00
Heavyweight, per hundred	45.00

Cans, galvanized, 4 by 5½ inches, for capillarity, moisture equivalent, etc. (Any sheet-metal works.)

.40

Drying ovens:

Hot-water bath, in various dimensions from 9 inches up	{ About \$50.00 and up.
Electric, Freas, type R No. 108, inside dimensions 16 by 14 by 16 inches, thermostat, thermometer, etc	

\$210.00

Hearson low temperature incubators, gas and electric heated, various sizes

140 to 360.00

Potentiometers and other electrical resistance apparatus.

Water-retention cup, for determining the maximum water retained by soil, of brass 2 inches in diameter by $\frac{7}{8}$ inch high, with diaphragm of perforated metal fastened about $\frac{7}{16}$ inch below top, No. 9295

0.20

Capillary moisture pans:

Hilgard's small circular metal pans, about 1 centimeter high and 4½ inches in diameter, with perforated bottoms for determining "capillary moisture" of soil, each	1.25
Per ten	10.00

Balances, glassware, reagents, etc. (Obtainable from all dealers in laboratory supplies.)

ATMOSPHERIC HUMIDITY.

The humidity of the atmosphere is directly reflected in any such water-containing object as the leaf of a plant, in which there is a constant tendency to come into vapor-pressure equilibrium with the atmosphere, usually through evaporation but in rare circumstances through absorption. The point of equilibrium between the leaf and the atmosphere will be better understood by considering the discussion which has preceded, in reference to osmotic pressures.

Although this constant tendency is nearly always causing the loss of water from plants, the humidity of the atmosphere alone can not be taken as a measure of the "evaporation stress," or rate of evaporation, depending on the wind movement which aids in diffusion of vapor, and the heat supply, principally from sunlight. For this reason, when a direct measure of the evaporation stress is possible through the use of some form of atmometer, ecological studies will not require the measurement of atmospheric humidity except in a somewhat perfunctory manner, as a means of detecting

errors in evaporation records, or possibly for comparing conditions locally studied with stations for which there is no evaporation record, but which maintain a complete record of wind movement, sunshine duration, and humidity. In such an event it may be possible to work out a fairly constant relation between the evaporation from any given type of atmometer, and a combination of these other conditions, properly integrated, in the general relation of:

$E(K) = (\text{Wind movement plus saturation deficit}) \text{ sunshine.}$

The term "vapor pressure" expresses the weight per cubic foot, or the pressure, in centimeters of mercury, of the vapor currently in the atmosphere. The term "saturation deficit" expresses the lack of vapor pressure, or the difference between the existing vapor pressure and that which the atmosphere would contain at the current temperature if the space were saturated with water vapor. The "dew point" indicates the temperature at which the existing vapor would condense; or, in other words, the temperature at which the existing vapor would produce a condition of saturation. It is readily seen, then, that the saturation deficit is the difference between saturation pressure for the current dry-bulb temperature, and saturation pressure for the temperature of the current dew point. The term "relative humidity" expresses, as a percentage, the relation between the existing vapor and that which might be present if the space were saturated at the current air temperature.

The dew-point figure is used only incidentally in computing vapor pressure, saturation deficit, or relative humidity. Of the three, experience in a number of forest ecological studies has shown that the saturation deficit is by far the most useful, giving, as it does without further reference to temperature conditions, a direct measure of the capacity of the atmosphere for more vapor, and hence, in some degree, a measure of the rate at which evaporation will take place.

The psychrometer, consisting of a pair of thermometers mounted on a frame in such manner as to be readily whirled in order to accelerate evaporation, is the common instrument for determining atmospheric humidity. One of the thermometers is covered with a layer of cloth (preferably linen), which is dipped in clean water before making the exposure. The evaporation of this water cools the thermometer, or, as the expression is, causes "a depression of the wet bulb;" and the maximum depression which it is possible to produce by vigorous movement of the instrument through the air, taken with the current temperature, is considered to give a measure of the atmospheric humidity. Tables have been worked out, after experiment, for almost all possible combinations of air temperatures and wet-bulb depressions, showing the corresponding dew points and relative humidities. Of these the best-known in this country

are the "Psychrometric Tables" of the United States Weather Bureau, contained in its Bulletin 235. These have been worked out for barometric pressures of 30, 29, 27, and 23 inches. In accordance with American custom, vapor pressures are given in inches of mercury. Through the courtesy of the Weather Bureau, it is possible to produce in the Appendix an additional Table of vapor pressures for a mean barometer of 21.42 inches, prepared by B. C. Kadel for the special use of the Wagon Wheel Gap Experiment Station, at an elevation of 9,300 feet. This table will doubtless be of considerable assistance in ecological studies in the western mountains.

The vapor pressure may also be determined very quickly and precisely by means of dew-point apparatus and a table of saturation pressures corresponding to various temperatures. This apparatus is, however, far less convenient for field use than the psychrometer.

The ideal record of humidity is, of course, one which shows the atmospheric condition for every hour of the day. Theoretically, this is obtained by the use of the hair hygograph; but, actually, the instrument is of very little use.

The atmospheric conditions are measured in terms of relative humidity, which fluctuates rapidly with every change in air temperature. The record must then be transposed, in conjunction with the continuous temperature record, into terms of absolute humidity and saturation deficit, before it can have much value. Furthermore, the hygograph is probably the least reliable and accurate of the automatic instruments commonly used.

Since the absolute humidity or vapor pressure usually does not change through a wide range in a short time, but shows a general tendency to increase as the air warms and to decrease with the cooling at night, it is possible to determine a fairly satisfactory mean humidity for any day (except of course during general disturbances) by means of two or three observations with the psychrometer. For example, the hours of 7 a. m., 1 and 7 p. m., have been used, or 7 a. m., 2 and 9 p. m. After hourly observations for a few days at any season and point, it should be possible to select one or more convenient hours when, in the ordinary sequence of events, the mean humidity of the day may be approximately measured, either at each observation, or through averaging unlike valuations. As has been suggested, the absolute humidity varies less than the relative humidity or saturation deficit. Therefore, for calculating the mean saturation deficit for the day it is logical to arrive first at the mean vapor pressure, and then, after calculating the mean temperature for the whole period, to obtain the saturation deficit by deduction.

If only one psychrometer reading a day is feasible, both the wet and the dry bulb reading may be entered in the first columns of the "Humidity, Wind, and Evaporation" form, and the relative humidity, vapor pressure, and saturation deficit calculated therefrom may be set opposite. When several readings are made each day, it is suggested that the calculated vapor pressures be recorded on the form for "Hourly (Air, Soil, or Actinograph) Temperatures" for their appropriate hours, and that only the mean vapor pressure be recorded on the "Humidity, Wind, and Evaporation" form.

The relative humidity, vapor pressure, and saturation deficit should be averaged by decades and months. The means by months, the year, and the growing season, should be shown on the annual "Summary" form.

INSTRUMENTS.

<i>Psychrometer</i> , sling, standard Weather Bureau pattern; aluminum backs; polished hardwood handles; double-length connections; 2 glass tubes, exposed, mercurial thermometers, 9 inches long; stem-graduated and figure on glass for each 10 degrees; Fahrenheit or centigrade.....	\$3. 00-\$6. 00
Whirling apparatus, stationary, complete (without thermometers).....	18. 50
Cog psychrometer, Thermometers about 4½ inches long, reading -5° to 50° C., No. 1230.....	4. 50
Hygograph (or self-registering hygrometer) complete with a year's supply blank forms. No. 58-B, pen and ink.....	80. 00

WIND MOVEMENT.

Wind movement may be effective upon plants both directly and indirectly: that is, through mechanical breakage, windfall, etc., and through its influence upon evaporation and transpiration.

While mechanical injury to trees by wind seems to be a less important factor in American forests than in those of Europe, judged by the literature on the subject, the problem of windfalls is one of ever-growing importance as forestry is extended and thought is given to the conservation of that portion of the stand which is not now merchantable or is needed as a guarantee of future reproduction. A recent article by Weidman (150) and several other articles that might be cited have shown the importance of the problem and the desirability of a great many more wind records than are now available for our forest regions, if the problem is to be scientifically solved. Perhaps this is a far cry from ecology. Yet a disturbance in the forest which is capable of starting a new succession is certainly of some ecological significance, at least after it has occurred.

Wind movement has without doubt a very marked effect on evaporation; and, in addition, the moving air may be either a source of heat or a means of dissipating the heat of sunlight, as suggested by

Bates (145) in discussing the actual measure of heat available for use in the plant. The first of these influences may be practically ignored, as was the case with humidity, if there is available a record which has integrated all the factors in evaporation. It is believed, however, that most ecological studies will be found deficient if the record of wind movement is not obtained.

To obtain a record of wind movement in the forest which may cause mechanical injury, the anemometer should undoubtedly be placed almost at the tops of the tree crowns, where the most severe winds will be encountered. A strong support is needed to prevent loss of record at the most critical times.

In the study of reproduction and of other shall plants, it may even be necessary to dig a pit for the stem of the anemometer in order that the cups may be close to the ground surface.

The standard Robinson anemometer is the most practical instrument for all outside work. Because of a friction factor, it underrates wind of low velocity such as is often characteristic of the forest floor, and slightly overrates the high velocities. The amount of wind movement may be read on the dial of the instrument to tenths of miles, and the anemometer may also be electrically connected to a register so as to give a record of each mile of wind movement. Because it records no less than a mile of wind movement, the Robinson anemometer is not wholly satisfactory from the standpoint of mechanical injury to trees. It is possibly more true in mountainous regions than elsewhere that the winds of greatest velocity are gusty, and it seems likely that the gusts of only a few seconds' duration may have at least twice the mean velocity recorded for whole miles. While daily or more frequent readings of the anemometer dial may be sufficient where a definite use of the wind record can not be foreseen, in many cases the occurrence of maximum and minimum velocities, the movement by day and by night, etc., as obtainable from the electrically operated register, will be desired. Since the current required for operation is only 2 or 3 volts, connection with the anemometer in the field may be made with the crudest sort of conductors, using wire fences, or insulated wire laid on the ground. In this way the register may be in a protected place and receive due attention.

Apparently the only apparatus capable of recording momentary high velocities is the Dines pressure-tube anemometer, the use of which in the forest is hardly feasible.

Wind vanes with connections and registering device are obtainable, and may possibly be desired at one station in a locality. There is, however, no ecological significance in wind direction; and if there were, it is probable that a single observation on prevailing direction each day and night would be amply sufficient.

HUMIDITY, WIND, AND EVAPORATION.

Type _____; Station No. _____; ^{cover} _____; ^{open} _____ cross out one;
 Month of _____ 19____

(Elev. of Anemometer)

(Elev. of Evaporimeter)

Date.	Humidity.				Wind movement.						Evaporation ³ (by), (Water or non-freezing solution.)										
	Dry bulb. F°	Wet bulb. F°	Rel. hum. %	Vapor press. Ins.	Sat. def. Ins.	Velocity.			Prevailing direction.			From hourly record ²			Read.	Water loss. Cm.	Re-filled to. Cm.	Read.	Water loss. Cm.	Re-filled to. Cm.	
						Time of ob.	Dial.	Movement.	Day.	Night.	24 Hours.	Max. Mov't 1 Hr.	Day Mov't.	Night Mov't.							
1.....																					
2.....																					
3.....																					
4.....																					
5.....																					
6.....																					
7.....																					
8.....																					
9.....																					
10.....																					
Dec. mean..	a	a					a								a	T		a	a	T	a
11.....																					
12.....																					
13.....																					
14.....																					
15.....																					
16.....																					
17.....																					
18.....																					
19.....																					
20.....																					
Dec. mean..	a	a					a								a	T		a	a	T	a

For all stations the dial reading should be recorded in the field at each observation, and the dial readings and total movements should be tabulated in adjacent columns of the "Humidity, Wind, and Evaporation" form. The decade means or sums and the monthly sums and means should be computed and entered. For most uses the decade sums will be preferable to means. The record of day and night movements may be obtained either from two dial readings per day, or from hourly automatic records.

Where hourly records are available, the greatest wind movement for any single hour of each day should be entered, and also the total wind movement by day and by night; that is, from 6 a. m. to 6 p. m., and from 6 p. m. to 6 a. m. This division of the daily movement is of interest in the general study of the climate, and may assist, for example, in determining relative amounts of evaporation during the day and night, when this is not readily determined directly.

The monthly, annual, and growing season means of the movements obtained from dial readings, and of maximum hourly velocities, and the sums of day and night movements obtained from automatic records, with the mean hourly movements computed therefrom, may be tabulated on the "Summary" form.

INSTRUMENTS.

Self-registering Instruments:

Single register complete (for wind velocity), with a year's supply blank Forms 1015, pen and ink (by special arrangement a register to carry wind record for one week may be obtained) ----- \$95.00

Two magnet registers—

No. 2, for wind velocity and sunshine (using Form No. 1015-C) ----- 125.00

No. 3, for wind velocity and rainfall (using Form No. 1015-D) ----- 130.00

No. 4, for wind velocity, rainfall, and sunshine (using Form No. 1015-E) ----- 140.00

Quadruple register complete (for wind direction, wind velocity, rainfall, and sunshine), with a year's supply of blank Forms 1017, pens and ink ----- 275.00

In all of the above, cable and battery for electrical installation are extra.

Anemometers, wind vanes, and supports:

Anemometer, Robinson's; of the standard pattern, complete with aluminum cups and wrench; all dimensions and construction to be identical and small parts interchangeable with corresponding parts of the anemometer of the Weather Bureau ----- 52.00

Anemometer cups, aluminum, with arms, G. S. S. No. 12200; per set ----- 8.00

Anemometer cups, copper, reinforced, .013 inch thick, hemmed at edges and arms reinforced, G. S. S. No. 12201; per set ----- 9.50

Wind vane; small, for towers, with mounting, complete, G. S. S. No. 12274 ----- 13.50

Anemometers, wind vanes, and supports—Continued.

Combined wind vane and anemometer support, 20 feet high, adapted for use with quadruple register; complete with 6-foot vane, electrical contacts, etc., but without anemometer-----	\$105. 50
Wind vane, 4 feet, on 7-foot support, with direction arms, gilt letters, and anemometer support, but without anemometer-----	35. 00
Wind vane and support, as above, but without anemometer or anemometer support arm-----	27. 50
Support for anemometer alone, without vane, direction arms, or anemometer-----	15. 00

EVAPORATION.

No ecological study can be considered comprehensive which does not take into account the desiccating power or "evaporation stress" of the atmosphere. While the water supply of the soil has been considered as the condition most directly determining the character of vegetation on a given site, and its rate of growth, almost equal attention must be given to the matter of the dissemination through transpiration of the moisture which reaches the plant. The evaporation rate in different habitats will perhaps be found to show greater variation than any other condition. It is especially valuable, when measured directly, because it gives the integrated effect of wind, humidity, air temperature and sunshine—an integration which can not be accomplished by any artificial means. While it is not to be expected that any instrument will integrate the effect of these different stimuli to evaporation in a manner corresponding to their combined effect on the plant, yet this is the object to which the greatest efforts have been bent and which has to some extent been attained.

The study of the evaporation factor may be made directly, of course, by observing the transpiration of plants in the field. While very desirable and not very difficult, this is perhaps less satisfactory than the instrumental method in reducing the conditions of the environment to physical terms. Since this discussion is mainly concerned with instrumental procedure in forest investigations, the instrumental method, even though less desirable than direct measurements of transpiration, will be considered first.

OBJECTS AND NATURE OF EVAPORATION MEASUREMENTS.

There may be two rather distinct objects in measuring evaporation rates, although in ecology there is only one. Climatologists, irrigation engineers, etc., may desire to know, for local conditions and for general comparative purposes, how much capacity the atmosphere possesses day by day and year by year to take up moisture when offered moisture, as freely as possible, from the surface of a body of water. Obviously this does not measure the capacity of the atmosphere, which could better be determined by humidity observa-

tions. For crude comparative purposes, however, the loss from a pan of water is probably as good a measure as any, of general, regional, atmospheric conditions, such as would affect lakes and reservoirs, provided only a standard exposure is employed.

In plant ecology evaporation rates are measured for the purpose of determining how great or how little evaporation tendency, or stress, the plant has to withstand and can withstand without injury. As has been pointed out by Bates (151) under any circumstances the components of evaporation are (1) the heat necessary to transform water into vapor, and (2) the diffusion possibilities of the vapor. In ordinary evaporation there are two possible sources of heat; namely, sunlight, or radiation from any other source, and the heat of the air coming in contact with the evaporating body. By diffusion possibilities are meant the net opportunities for the vapor to move away from the evaporating body. These depend on mechanical obstructions, on the number of vapor molecules already in the atmosphere, on the air movement near the evaporating body affecting this number, but most of all on the temperature, energy, and pressure of the molecules which are moving away. Hence sunlight and almost every atmospheric condition affect evaporation, and it is also plainly evident that each of these factors can not have an identical effect on each of several different evaporating bodies. To use an extreme example, a highly polished metal vessel containing water might be set in full sunlight, and yet the evaporation of the water would not be appreciably influenced by the sunlight, because the heat of the sun would not reach it—the rays would be almost totally reflected. Similarly, the evaporating body may be very largely protected from wind, so far as the wind might affect diffusion. This is to some extent the case in the leaf, where the vapor is largely formed internally.

When, therefore, it is said that in ecology an atmometer is desired which will react to the same external stimuli as affect the plant leaf most directly, it is not by any means implied that the instrument would parallel the plants' transpiration under all circumstances. There should be a certain similarity in their reactions when both are reacting freely. It is not desirable to compare an instrument which is mainly susceptible to wind with a plant which responds in the largest measure to sunlight. If there could be an atmometer which would receive its stimulus from sunlight, wind, air temperature, and humidity in about the same proportions as these four factors affect the plant, the evaporation factor of the habitat could be measured in an effective way. Otherwise, altogether too much emphasis may be placed on some one component, such as wind. After all is said this is almost exactly the same problem as attempting to integrate

mathematically the effects of the several components on the evaporation from the plant. One is just as far from an absolutely precise outcome as the other. The advantage of the atmometer is that, once the integration has been accomplished in the construction of the instrument, the observations are relatively simple and no further complex calculations are necessary.

As has been suggested, it is not to be presumed that the atmometer will show restricted evaporation due to control, as may be the case with the plant when it closes its stomata or when transpiration is automatically reduced by increasing density of the cell sap. By comparing the most perfect atmometer with plants, however, it should be possible to measure the actual effectiveness of these plant controls.

It may be worth while to suggest, for the sake of more effective evaporation studies, that it is possibly erroneous for the student of plant life to look upon a large evaporation factor in the habitat as necessarily inimical to the plants which are there. Some theoretical considerations which point to transpiration as a benefit have already been outlined. No attempt will be made, however, to decide the question as to whether it is beneficial to the plant or merely a necessary evil. Laying this question aside, it is perfectly evident that conditions conducive to high transpiration rates are an unavoidable concomitant of the conditions necessary to active photo-synthesis.

When therefore, as in Weaver's (169) succession from prairie to brush or woodland types, it is found that succession produces a steadily decreasing evaporation rate, shall it be concluded that the plants of the brush stage are directly favored by the decreased evaporation, only relatively favored, or not helped at all, but merely able to succeed with less sunlight than the plants of the prairie? Very likely, in a case of this kind, the rate of evaporation, while a serviceable index to the general conditions, may not itself be a controlling factor, or may be a controlling factor only for a brief period in each season when drought occurs. It would appear to be all-important that evaporation rates be closely correlated with the moisture of the soil, as is done by Shreve (166) in giving directly, if somewhat crudely, the ratio of evaporation to soil moisture contents in various habitats. What is perhaps more important is that a clear distinction should be made between evaporation stresses when there is an abundance of soil moisture, and those existing when the moisture supply is nearly exhausted. There are, also, critical periods brought about by excessive evaporation when the soil moisture is apparently all that it should be. These and their effects must be separately analyzed.

The main object of this discussion is to make clear the need for evaporation records day by day, and for a finer analysis of the seasonal records than has been the custom in recent ecological studies.

INSTRUMENTAL METHODS.

The instrumental methods of measuring evaporation may be of two kinds, employing respectively free-water bodies, as in the open tank, and evaporating surfaces which are kept continually moist but in which the water is retained and to some extent withheld from evaporation by capillary action. The latter, for brevity's sake, will be spoken of as nonfree-water methods and instruments. The literature of instrumental evaporation studies is very extensive and has been fully annotated by G. Livingston (162). This discussion must be confined to a few of the more recent efforts.

FREE-WATER SURFACE.

The free-water surface receptacle is used almost exclusively in broad climatological and irrigation studies and only to a limited extent by ecologists. The Weather Bureau has now adopted a standard free-water surface evaporating pan, 10 inches deep, 48 inches in diameter, and constructed of 22-gauge galvanized iron, which is described by Kadel (155). Largely through the work of Bigelow (152), it was determined to be essential, that the receptacle have a surface of known area, that the water exposed in the pan or tank have a known volume, that the surface of the water have a known and as nearly constant distance below the margin of the vessel as possible, and that the material and shape of the receptacle be the same in all cases. All of these conditions are principally effective on the temperature attained by the water, and variation in any one of them is apt to affect the evaporation. The size of the vessel and the water it contains, for example, have much to do with the hourly rate of evaporation. A small vessel of a given aerial surface and depth will give a higher evaporation than will a vessel five times as large, since the water in the smaller vessel will more readily adjust itself to conditions of the surrounding air than the water in the larger pan. The temperature of the evaporating medium, of course, is of great importance in determining the rate at which vapor rises from a pure liquid. It is now the standard procedure to select a very open site for evaporation measurements, avoiding objects which might shade the pan or give it reflected light. The pan is placed on a low platform or crib, only a few inches above the ground, yet allowing air circulation all around it.

Measurements.

The amount of water evaporated is determined by the use of a hook gauge, the loss in any 24-hour period being corrected for pre-

precipitation, in accordance with the measurement in a standard rain gauge nearby. The evaporating pan is filled to a depth of 8 inches at the outset, and refilled to this amount whenever the water has receded an inch. The water is occasionally freshened by a complete change.

NONFREE WATER SURFACE.

There are three instruments which have been sufficiently used in this country in recent years to warrant discussion. Each of these three exemplifies a different technical idea.

Piche evaporimeter.

The Piche evaporimeter, as modified by the Weather Bureau, was used considerably 10 years ago and has been described by Russell (164). It consists of a graduated glass tube as a reservoir for the water and a filter paper held over the open end of this tube by means of a horizontal glass plate, a spring, and a pressure screw. It is commonly equipped with a 10-centimeter (4-inch) glass plate and a 9-centimeter filter paper under ordinary conditions, or a 5½-centimeter paper of the same make when evaporation is likely, between observations, to exceed the capacity of the tube, about 40 cubic centimeters. The larger paper exposes 60.91 square centimeters and the smaller 21.06 centimeters. Therefore, quantities evaporated from the smaller papers should be multiplied by 2.891 to make them approximately comparable with the others.

Distilled water should be used in evaporimeters, both because of the effect of soluble substances and to keep the instruments clean and free acting. A nonfreezing solution of 25 per cent denatured alcohol and 75 per cent distilled water has sometimes been used in cold weather; but the value of records obtained under such conditions is questionable, because at times the evaporation is almost wholly from the alcohol, and the ratio between alcohol and water or ice would, of course, depend very largely on the temperature. For this reason the instrument can not properly be considered for freezing weather.

The regulation of pressure on the glass plate is a somewhat complicating and bothersome factor. In dry weather the pressure must be made light to feed the paper sufficiently, and in damp weather it must be quite firm to prevent overflowing on to the glass, if not actual dripping.

Evaporimeters of this kind may best be suspended on wires, having hooks at their lower ends, so that the instruments may be readily taken down for filling. In filling, a long 50-cubic centimeter pipette is found most convenient, making it possible to keep the outside of the

tube dry. Care should be taken to have the filter paper wetted and adhering closely to the glass before the instrument is read and left.

It is unnecessary to calibrate these instruments, because of the frequent changing of the filter papers and the fact that papers of one grade may be quite uniform in their capillary properties. Beyond this, the evaporation rate is somewhat controlled by the adjustment and the degree to which the paper is wetted.

The Piche evaporimeter is not now considered so desirable an instrument as some of the other types. Though it is simple and fairly easy to operate under most circumstances, it is fragile and hardly suited to severe weather conditions; the adjustment of the feeding for changes in the weather is always vexatious and sometimes beyond one's power; a correction for rainfall is out of the question; and the technical point may be raised that the moist surface is somewhat too freely exposed to wind, while the white filter paper absorbs only a small proportion of incident radiation. The conditions for evaporation are therefore very different from those within the leaf.

Porous-cup atmometer.

The name "atmometer," while describing any instrument for the measurement of evaporation from a moist surface, is usually associated with evaporimeters of the porous cup type. A very satisfactory field instrument of this type has been described in several papers by Livingston (159), and may be obtained on the market either with or without standardization. Only standardized instruments should be used in comparative studies. The instrument consists of a closed cup with porous walls, into which the water is fed at any desired pressure by regulating the height of the reservoir. The reservoir, connected with the cup by rubber tubing, may be a flask of any size or a graduated tube. In the former case, the amount of evaporation in any specified period may not be determined directly, but rather by measuring the amount of water required to fill the flask to its original level. This feature is inconvenient, but the use of a large flask so increases the possibilities of the instrument for long-period observations that it is, in this respect, far superior to the Piche evaporimeter.

The moisture of the cup reaches the outer surface through the porous walls, its rate of movement being determined by the internal pressure and also by the difference in capillary tension caused by the loss at the outer ends of the pores. Presumably capillary movement is sufficiently rapid to maintain the supply at the outer surface at any reasonable rate of evaporation. Yet there must be a limit to this capillary action in both directions, and for this reason the movement must, under extreme conditions, be governed

somewhat according to atmospheric conditions by regulating the hydrostatic pressure. With the outside walls of the cup always moist and yet not dripping, the rate of evaporation will of course be governed by atmospheric conditions. It must not be expected, however, that the evaporation from this instrument may be compared under a variety of conditions with that from the Piche instrument, or with that from a free-water surface. While the absorption of heat from radiant sources and conduction from the air will be practically the same for the water surfaces in the three cases mentioned, yet the further absorption beyond the first water surface will depend on the nature of the substance behind that water surface—in the one case, water; in the second, paper and glass; in the third, clay or some similar earthy substance. Therefore, the three instruments will respond quite differently to the stimuli of warm air and sunshine.

For these reasons, comparative data will be of value only when the same instrument is used in all measurements of the comparison.

Shive's nonabsorbent porous cup atmometer.

It has been the experience of various investigators that the Livingston porous cup atmometer measures the evaporating power of the air with a very considerable degree of accuracy during periods when the temperature is not recorded at or below zero centigrade.

In 1910, Livingston (158) described a rain-correcting atmometer. This atmometer, while giving great satisfaction in the hands of many inexperienced workers, was difficult to operate in some localities. Thus it was found impossible to obtain continuous records in the dry climate of the Wasatch Mountains of the Manti National Forest in central Utah, principally on account of the connections and joints of the equipment, all of which occurred outside of the water reservoir. Hail storms and objects carried by strong wind were often so severe as to disjoint or break the more delicate equipment. In connection with this instrument, it is understood that the automatic mercury valves which operate to prevent the water absorbed by the porous cup in times of rain from entering the reservoir are externally situated. This makes it essential to have all valves very tightly connected in order to prevent leakage. Much to the satisfaction of those who have used this instrument, Shive (165) has described one so modified as to be self-contained, and at the same time to reduce to the minimum the liability of breakage and the difficulty of adjustment. This was accomplished by eliminating jointed mercury valves and decreasing the leakability and breakage to a nominal degree. The arrangement of the different parts of the

instrument is shown in the following detailed diagram (fig. 4). The description of the self-contained instrument, which is particularly adapted to general field work, is quoted from that prepared by Shive.

From the reservoir (F) two glass tubes (A and B) extend upward through a paraffined cork stopper, and then through a two-perforated rubber stopper into the porous cup, one passing to the tip of the cup, the other just to the upper surface of the rubber stopper. These tubes are of small bore, about 0.8 millimeter inside diameter. Each is bent into a U and continued upward as A' and B'. One (A') extends through the paraffined cork (B') extends upward 6 centimeters to 8 centimeters and is stopper and ends about 5 centimeters above it. The other again bent near the bottom of the reservoir. The tube B is expanded into a small bulb C at its lower extremity, and the tube A' is expanded into a similar bulb 1 centimeter to 2 centimeters from its lower end. The tube E is about 1.2 centimeters in diameter, and forms a shallow, inverted funnel with the lower surface of the paraffined cork stopper. This serves to conduct air bubbles, which may catch on the under-surface of the stopper in filling the reservoir, to the exterior. The tube extends 5 centimeters above the cork stopper and is graduated to tenths of cubic centimeters. The zero point on the tube serves as a zero point in filling the reservoir.

To install the instrument the paraffined cork stopper, into which the tubes A A', B, and E have been properly fitted, is tightly pressed into the mouth of the reservoir F. A sufficient amount of clean mercury is allowed to fall from a pipette into the openings in the upper end of each of the tubes A' and B to form a column 5 centimeters to 6 centimeters high in tube A', and slightly more than this in tube B. After the porous cup has been placed in position and the reservoir filled with distilled water, a rubber tube is attached to the free end of the filling tube A', and gentle suction is applied. Water rises from the reservoir into the tube B', at the same time that the mercury in this tube is drawn into the bulb C, where water passes freely and rises in the tube B, filling the porous cup. When the cup is filled, water passes into the tube A A', the mercury in this tube having been drawn into the bulb D, where the water is allowed to pass freely and escape into the rubber tube, which is then removed. The mercury in the bulbs C and D drops back into the tubes below. To prevent water loss from the reservoir by evaporation through the tube E

and to prevent the entrance of water through this tube from without in times of rain, a vial is placed over the end of this tube. A suitable vial is also placed over the end of the tube A' to exclude dirt. The instrument is now ready for operation.

To replace the cup with a new one, it is only necessary to remove the old cup from its support and to place the new cup into position, after which suction is applied to the tube A', as in installing.

As water evaporates from the surface of the cup, the mercury rises in tube A and falls in tube A', coming to rest with the mercury level in A, slightly

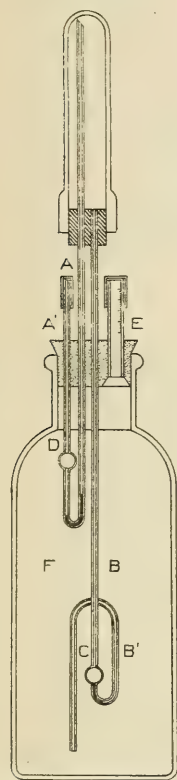


FIG. 4.—Shive's nonabsorbent porous cup at-mometer.

higher than in A', the difference in the height of the two columns depending upon the height of the cup above the water level in the reservoir. The mercury in B B' is drawn into the bulb C, where water rising from the reservoir is freely allowed to pass, supplying in the usual way the water lost from the surface of the cup. The mercury columns in the tube A A' and B B' remain in equilibrium in the position indicated in the figure, so long as the water loss from the surface of the cup by evaporation equals or exceeds the absorption from without by any part of its surface. In times of rain, when the water loss from the surface of the cup by evaporation is less than the absorption from without, the automatic mercury valves become reversed. The mercury column falls in A and rises in A' at the same time that the mercury in bulb C drops into the tube below and rises in the tube B' (the height to which the mercury rises in this tube depending upon the height of the cup above the water level in the reservoir), thus effectually preventing water from entering the reservoir from this direction. The readings obtained give the actual evaporation minus the error introduced by the volume change required for the operation of the mercury valves, the value of the error thus introduced depending upon the number of complete reversals of the valves.

Standardization.

The Livingston porous-cup atmometers, whether to be used with or without the Shive nonabsorbing apparatus, should be obtained in the standardized form, which insures comparability of the results obtained with different instruments and by different investigators. This standardization of the instruments is one of the strongest features, making it possible, for the first time, for different investigators to speak of evaporation in common terms. Since the standardizing can not be readily accomplished in the field, it is sufficient to state that it is very carefully done at the Johns Hopkins laboratory, where each new instrument is compared with one or more tried instruments. Assuming the rate of evaporation for a certain time to be 100 in a standard instrument, the coefficient of an instrument which in the same period evaporated 150 units, would be 0.67. In short, the coefficient given, for any instrument which has been "standardized," is the amount by which all records of that instrument should be multiplied, to reduce them to a standard basis.

Computation of field results.

In computing the field results to a standard basis, all cups used for a few days or weeks are restandardized. Provided the new evaporating coefficient is found to differ from the original, the probable average coefficient during regular cycles or periods is calculated. It has been shown experimentally that the change in the evaporation coefficient takes place gradually and uniformly during the period of operation (159). Thus, assume that a given atmometer cup having an initial coefficient of 0.62 was exposed in a habitat for a period of four weeks during which it was read three times; namely, at the

end of the first, the second, and the fourth week. Upon standardization after the last reading (that is, after the end of the fourth week), the cup, suppose, had a coefficient of 0.70 in place of the original coefficient of 0.62. A variation of 0.08 is therefore to be distributed uniformly over the four-week period. At the end of the first week the assumed coefficient is 0.62; at the end of the second week it is 0.66; and at the end of the fourth week, 0.70. According to the above assumption, the average coefficient for the first week would be 0.63; for the second week, 0.65, etc. Assuming, then, that the reading at the end of the first period—that is, at the end of a week—was 500 cubic centimeters, by reducing to standard units

we have the standard reading $\frac{500 \times 63}{100} = 315 \text{ c. c.}$

Exposure.

This instrument will operate over a long period, the time depending upon the size of the reservoir and the exposure to the evaporating power of the air. For this reason the instrument may be exposed upon remote habitats where weekly, bimonthly, or even monthly readings may be made. Records of this kind, of course, are less conclusive than those made at more frequent periods, but nevertheless have a high value for comparative consideration. Readings taken only bimonthly or so are accurate because of the permanent, rain-correcting adjustment of the instrument, a point which has already been brought out in detail.

Since the instrument is compact and light in weight, it is possible to make the exposure practically wherever desired. If, for example, the investigator desires to determine the evaporation rate near the surface of the ground amidst low-growing, herbaceous vegetation or arborescent seedlings, the reservoir is sunk in the soil so that the evaporating surface of the atmometer is exposed at the height desired. In cases where the evaporation rate is desired at various heights, the instruments may be placed at definite vertical elevations on light supports running out horizontally from a common vertical beam.

The principal disadvantages mentioned with respect to the Piche evaporimeter have been eliminated in the construction of the porous cup with its nonabsorbing attachments. It is of simple construction, not extremely expensive, occupies a small space, and may be equipped with a reservoir which will keep it in operation for an indefinite period. Wind does not disturb it, and small animals and insects have no effect upon its operation. The disadvantages are that the bottle, connecting tubes, and especially the delicate nonabsorbing apparatus are rather easily broken by inexperienced hands, or by roving animals such as domestic stock and deer. A still more serious

difficulty is the sensitiveness of the instrument to frost; the slightest freezing of the water in the connecting tubes drives the mercury out of the valves and generally bursts the tubes, which are the most expensive part of the instrument. Even when the air temperature is not below 32° F., but the wet-bulb temperature is below freezing, ice accumulates on the cup in large quantities. In short, the instrument is worthless when the temperatures approach freezing.

Other disadvantages are the necessity for frequent restandardizing, and the occasional failure of the cup to draw moisture from the reservoir as fast as evaporated. This permits the entry of air, and reduces the evaporating surface, entirely vitiating the results until the cup is refilled.

Forest Service evaporimeter.

To fill the need, in forest studies, for a substantial, essentially indestructible evaporimeter, operating as well in winter as in summer (since it can not be conceded that biological activity ceases with the first occurrence of frost), Bates (151) has designed a metallic, "inner cell" evaporimeter. In addition to these desired practical qualities, it was conceived that an evaporimeter might more closely resemble the leaf, and thereby might show a closer correlation with plant transpiration, by having the evaporating body somewhat protected from air currents. Evaporation takes place in the leaf, not largely on its surface; and, while transpiration is accelerated by wind movement, the latter can not have the direct action upon the water in the leaf and its formation into vapor that it has upon a fully exposed surface.

The correctness of this principle has been demonstrated by comparative tests of evaporation and transpiration under a variety of conditions. The evaporimeter may be briefly described as follows:

The tank or reservoir has a capacity of about 450 cubic centimeters, sufficient for a week's operation under extreme conditions. It is seamless and is not ordinarily injured by freezing. It is protected by an outer shell of polished metal, which insulates it both against temperature changes and against direct radiation.

Out of the tank rises a stem a few inches long and one-half inch in diameter, carrying the feed-wick, which is a piece of linen rolled into cylindrical form with the threads "drawn" at one end. At the top of the stem this wick is flattened out to make a contact with the evaporating wick. The evaporating wick is a flat, circular piece of linen having an area of 100 square centimeters. It rests upon a perforated metal disk of the same size, the perforations aggregating an area of 5 square centimeters, and designed to simulate the stomata of the under side of a leaf. All vapor formed must escape through

these perforations. The disk is firmly attached to, and flush with, the upper end of the stem.

Over the wick is a cover only slightly larger than the disk, whose flanged edge extends down over the edge of the disk. This is held down by two screws, which engage the flanged edge. The cover is flat, but seamless, and completely excludes rain or snow. Its surface is finished with nickel and an instrument having this polished surface absorbs practically no radiant energy and is called a "shade" instrument. To obtain the effects of radiation, an instrument whose cover has been coated dead-black is used. The "shade" instrument is now entirely abandoned, since it has been seen that the difference between the two is not a measure of sunlight intensity, but a measure of the additional effect of sunlight in producing evaporation. This effect can not under any circumstances be ignored in ecological studies.

The tests which have been made show that the losses from the blackened instrument of this type follow more closely those from potted trees, under a great variety of atmospheric and solar conditions, than do the losses from any other type of instrument at present available. The instrument has also shown itself remarkably free from annoying characters, and responsive to all degrees of evaporation stress. It may be considered, however, something of a disadvantage that the amount evaporated is relatively small. The losses for short periods may, therefore, only be determined by very precise weighing.

OBSERVATIONS.

With the Forest Service evaporimeter the daily observations consist in weighing the instrument, usually on an inexpensive balance such as the Harvard trip scale. Refilling is undertaken as often as necessary to maintain between 100 and 200 cubic centimeters of water in the tank. The "closing" weight and "refilled" weight are entered on the field observation form, together with the number of the instrument. Computations of losses are usually made when entering the data on Form 8, and the correction in accordance with the calibration of the instrument is usually applied only to the total losses for 10-day periods.

With porous cups the daily or periodic observations will usually consist in an entry of the amount of water required to fill the reservoir to datum level. A graduate is taken into the field to measure this amount.

In the case of the Piche evaporimeter, losses are calculated from the readings of the graduated reservoir. Note should always be made of observed overflowing or drying-up of the filter paper or evaporating surface, and the probable correction due to these failures of the instrument should in all cases be estimated and entered

in the "Corrections" column of the field form "Daily Observations." Interpolations of this character should be indicated by asterisks on the "Humidity, Wind, and Evaporation" form.

TABULATION.

The tabulation of evaporation data on the "Humidity, Wind, and Evaporation" form consists in setting down all of the recorded weights of the evaporimeters, or graduate readings, and the losses computed therefrom. In the record for porous cup atmometers, there will usually be but one entry for each observation, though these instruments may also be handled on a weight basis more satisfactorily than on a volume basis. The corrections for calibration are made usually on the sums for 10-day periods.

Form Z

Daily observation at

Date or station No.....					
Time.....					
Datum:					
Maximum temperature, air.....					
Minimum temperature, air.....					
Current temperature, air.....					
Current thermograph pen.....					
Psychrometer:					
Dry bulb.....					
Wet bulb.....					
Anemometer dial.....					
Soil temperature:					
Surface.....					
1 foot.....					
2 or 4 feet.....					
Curr. thermograph.....					
Evaporimeter—Number:					
Closing reading.....					
Refilled to.....					
Amount since last ob.....					
Evaporimeter—Number:					
Closing reading.....					
Refilled to.....					
Amount since last ob.....					
Current precipitation:					
Water, inches.....					
Snow, inches.....					
Snow on the ground, inches.....					
Frost (indicate by X or XX).....					
Barometer, inches.....					
Phenology:					
Tree 1.....					
Tree 2.....					
Tree 3.....					
.....					
.....					
.....					
.....					

Date or month

Initials of observer

The annual summary of evaporation should be made on the "Summary" form and should consider the total evaporation by decades, months, the year, and the growing season. It may also be desirable to record the maximum rate noted during each month or decade.

DIRECT TRANSPIRATION METHODS.

In evaporation studies connected with plant life the chief purpose is to obtain in as simple a term as possible a measure of the habitat conditions, as they may affect transpiration. The response of the plant to these conditions will be governed by physical facts that can be fairly well comprehended, and by biological conditions which are still more or less obscure. While, then, transpiration studies may be made in lieu of evaporation studies, it will be far more profitable to consider the one as supplementing the other, giving an insight into plant functioning which can only be obtained as observations are reduced to terms of well-known physical laws. One of the means of determining the intensity of transpiration is by the aid of cobalt chloride paper.

Cobalt-chloride method.

Although the actual amount of water transpired by a plant can not be ascertained by means of the standardized cobalt-chloride paper, this method is particularly adapted to field use where merely relative rates of transpiration are desired, and for showing variations in rate with changes in environmental conditions. It is hardly necessary to point out that it would be almost impossible to apply to needle leaves. The method depends upon the fact that paper impregnated with a weak solution of cobalt chloride is blue when dry, but when exposed to moisture gradually turns pink. Specially prepared "tripartite cobalt-chloride paper slips" may be purchased. These slips are made up of three small strips of paper—a deep blue standard, a light blue standard, and between them a strip of cobalt chloride paper. In practice the strip is heated over a small flame or heated surface until the cobalt chloride strip is of a more intense blue than either standard. It is then applied to the surface of the leaf under consideration and held by small glass clips. When the cobalt chloride strip fades so that it matches the bluest standard, the time is noted. When it fades further and matches the light blue standard, the time is again noted and the elapsed time is recorded. This process should be repeated several times to assure a good average. A thermometer should also be hung amidst the foliage to give the temperature of the leaves.

The time taken for the cobalt-chloride paper to make the change in color between the two standards is the measure of the rate of trans-

piration of the leaf. In order to refer this to a definite standard, it is compared with the time required by the strip to make the same change over a free-water surface blanketed by one millimeter of air at a temperature the same as the leaf. The reaction time of each slip must therefore be ascertained under standard conditions. The apparatus for making these standardizations is described in detail by Livingston and Shreve (161).

It would obviously be a great labor to determine the reaction time of each slip for every temperature likely to be used; but this is unnecessary, because if the time is determined for one temperature it can be easily derived for any other, since it is inversely proportional to the pressures of saturated aqueous vapor at the different temperatures.

The chief objection to the method is the large personal equation involved. The fading of the slip is very slow indeed, and no perceptible change may occur for many seconds. Practically the system seems to work out well and yields much more consistent results than potometers. It is easily used in the field and in all kinds of sites, and appears to be a valuable addition to field research methods.

Method of excised twigs.

In measuring transpiration by means of cut twigs placed in potometers, the actual amount of water given off per unit of leaf surface can be determined.

The apparatus used consists of a flask closed with a two-hole rubber stopper, in one hole of which is inserted a glass tube bent at right angles: in the other the twig is sealed. The horizontal section of the glass tube is graduated so that it may be used to measure the water removed by the twig, and is drawn to a fine point at the end to minimize evaporation from the end of the tube. The twigs must be cut off under water and the ends must be kept continuously wet, or large variations in transpiration will occur. The sealing into the potometers must be very carefully done also, as the least leak will totally vitiate results. This method is particularly useful when it is desirable to determine transpiration of several species or in several sites simultaneously. The results tend to be erratic, however, and accordingly the determinations should be made in duplicate, at least to avoid gross errors. The same twigs can only be used for a short time, after which fresh ones must be obtained.

To determine the leaf area, as must be done to reduce the transpiration to amount per unit surface, the simplest method is to cut a number of pieces of known area with a cork cutter, or preferably a centimeter punch, weigh them, and then weigh the residue of the leaves and figure their area proportionately.

Method of potted plants.

The method of determining the transpiration rate, either in the laboratory or under a variety of field conditions, by means of potted plants, is theoretically the most reliable, since, if the potted plants are kept in a healthy condition and the moisture supply in the soil is properly regulated, a very near approach to natural growth conditions may be obtained. Unquestionably, the rate of transpiration is limited by the moisture supply. Where tests of this character are made in the field the moisture content of the pots may at all times be similar to that of the native soil at the point studied, allowance being made, of course, for differences in physical properties of the two soils, if any exist. A much simpler method is to maintain the pots constantly at a standard moisture content known to be near the optimum. Thom and Holtz (168) and Kiesselbach (156) have shown that the maximum transpiration occurs when the soil is about half saturated. This may be the result of aeration, or it may be that "about half saturation" corresponds to the "critical moisture content" of Cameron and Gallagher (117), in which case it is more likely to be a question of osmosis.

A method of treating plants that seems especially adapted to good-sized trees is that of Briggs and Shantz (153, 154), having been employed to determine the amount of water used by various agricultural crop plants under semiarid conditions at Akron, Colo. These tests were made on a large scale, with all arrangements designed for outdoor exposure. The pots were galvanized ash cans, through the covers of which the stems of the plants were made to extend after growth had become well established. The weighing of such pots was laborious, of course, and required the use of a traveling crane arrangement, by means of which the cans were lifted to the scales for each weighing. A very similar arrangement would appear practicable for determining transpiration from tree specimens, until they had attained the height of at least 4 or 5 feet.

For the convenient handling of forest tree seedlings up to 5 or 6 years of age, a galvanized iron can, 4 inches in diameter and 10 inches deep, has been used by Bates (105). This can is soldered and there are no perforations in the bottom through which water can escape. Before the seedlings are potted, a 2-inch clay flowerpot is inverted in the bottom of each can. Through the hole in the base of the flowerpot a glass tube of small bore, bent with two right angles so that the main part of the tube rests against the wall of the galvanized can, is inserted. It extends slightly above the wall of the can. This glass tube serves to feed water into the porous pot, whence it is readily diffused through the soil, and at

the same time permits the entrance of air, which may be obtained by the roots through the walls of the pot, insuring their maintenance in a healthy condition.

For the best distribution of moisture in the soil, it is desirable that a second tube, or a tee connection on the longer one, should be placed so as to extend about an inch below the soil surface. Since there will be some escape of vapor from each of these tubes, a pot similarly prepared, but containing no tree, should be run as a measure of such loss, under the various conditions to which the trees are exposed.

The weight of the can, pot, and glass tube is first obtained. The seedling to be potted is then weighed with the minimum of exposure to the air. The seedling is then placed in the can, which is filled with moderately dry soil, and the weight of the whole is obtained immediately after potting, following which water may be given to the plant. Having now the weight of the air-dry soil which has been placed in the pot, its net oven-dry weight may readily be computed, after drying small samples of the same soil; and from this net weight may be calculated the amount of water which the pot should contain at all times to maintain a moisture equal to 50 per cent, let us say, of the saturation capacity of the soil. Once the soil is well settled by watering, the top of the can is sealed with a mixture of paraffin and vaseline. A measured amount is used, so that the weight of this substance may also be included in the total weight which the outfit should show at the desired moisture condition.

Knowing the weight which the outfit should have at a certain moisture condition, the simplest method of measuring the transpiration is to put the can on one side of the scales and the desired weights on the other side, and to inject water from a burette until a balance is obtained. The water may alternately be injected through the long and the short glass tubes.

The transpiration results will be most expressive if given in terms of transpiration per unit of leaf area: but since, with coniferous seedlings, the determination of leaf area with any precision is next to impossible, the plan of computing the loss per unit of weight of the plant may be considered.

Where a number of plants, even though of the same species and grown under the same conditions, are to be placed in potometers for transpiration study under a variety of field conditions, the plants should by all means be calibrated under the same conditions before being distributed, since extremely great variations in individuals seem to be inherent.

INSTRUMENTS (APPROXIMATE PRICES).

Piche evaporimeter, modifications used by Weather Bureau; graduated to 0.2 cubic centimeter, capacity about 40 cubic centimeters. Supplied with glass plate 9 centimeters in diameter, and 1 dozen paper disks, No. 345 <i>b</i>	\$6.50
Paper disks for evaporimeter, per dozen, No. 345 <i>c</i>	.25
Livingston porous-cup atmometers:	
Natural cups, cylindrical with smoothly ground surface, for general purposes	.50
Coated cups, glazed at base, with permanent numbering	.60
Spherical cups, standardized	1.00
Shive's nonabsorbing attachment	6.00
Forest Service evaporimeters, equipped with wicks, blackened and calibrated	11.00
Evaporating pans, 10 inches deep, 4 feet in diameter, constructed of No. 22 gauge B. W. G. galvanized iron; can be constructed locally or secured through the United States Weather Bureau.	
Cobalt-chloride paper slips, "tripartite."	
Clips, glass, for attaching cobalt-chloride paper to leaves.	

PHENOLOGY.

The prevailing idea of ecology as a science through which the mysteries of plant and animal life may be solved merely by measuring the environment in more or less exact terms, is gradually giving way to a conception of ecology as a phase of physiology. In the preceding sections it has been attempted to bring out the concept of physiology, at least in its broader aspect, as a basis for those observations and measurements which are commonly associated with ecological studies. Unless the nature of physiological reactions in the plant is understood in a general way, the stimuli which are important to plant life, can not be correctly measured; that is, the environment can not be measured in terms which are expressive. On the other hand, each such effort, by reducing the stimulus to physical terms, permits a little better understanding of the activities of the plant, by placing them more nearly on a physical basis. Thus physiology and ecology must advance side by side, or, to use a crude simile, like the tread on a caterpillar tractor, in which each segment is in turn brought forward to a point where it may perform its temporary function.

Now, in fact, phenology is ecology as applied to functions of plants and animals which are more or less regularly periodic or seasonal in character. Unfortunately, much good effort has been wasted on phenological observations, particularly in connection with trees—wasted, because no correlation was attempted between the phenomena of growth and any other condition except time, calendar dates. Again, effort has been wasted because, while correlation between growth and climatic conditions was attempted, the observations on

growth particularly were too crude; no means was at hand of determining closely when growth began, how rapidly it proceeded, when it ceased. In consequence, phenological observations have fallen into disrepute.

The object of these conclusions is to suggest that, after all, in the study of ecology there is nothing more important than the behavior of the plant itself, its reactions at various times and seasons; in other words, phenology in the fullest sense. Otherwise, ecological studies may as well be left to climatologists and soil physicists.

How, then, may observations on the plant be made worth while? The observable external phenomena which accompany a reaction to certain environmental conditions must be measured more precisely than in the past if they are to serve any useful purpose. There is room here for instrumental development, quite as much as in the study of the environment. The field has been even more neglected. Again, there is opportunity for studying changes in the plant through internal physical and chemical conditions. This brings this study directly into the field of physiology, which can not be covered further than has already been done. Finally, experimental physiology, or the study of reactions to a limited change in environment, most of the conditions being stable and under control, is necessarily a laboratory study. The nature of the studies involved has been indicated in preceding discussions, especially in connection with light and soils studies. They may have a very useful result in showing how better to study conditions in the field, but they do not take the place of field observations. The reactions produced by changing one factor while other conditions are more or less perfectly controlled, may not be at all the same as in the field where all the factors vary synchronously. After all, then, the problem for the ecologists simmers down to one of determining plant reaction in the field as closely as possible.

In the past the plant society has perhaps been used too much as an index to reactions: that is, the effect of environmental conditions has been judged almost wholly by end results, in which competition plays an important part. A plant is either absent from a given site, occasional, abundant, moderately successful, or vigorous and dominant. From this is judged the extent to which the species is favored or inhibited by the environmental conditions that have been measured. This method is altogether too gross and undoubtedly has led to a great many erroneous conclusions. A great deal more is to be learned as to the requirements of different species by closer observation of individuals.

EXTERNAL FIELD OBSERVATIONS.

At each station where the environment is being studied, one or more individual trees should be permanently marked and numbered, and their condition should be a matter of daily observation. The number of trees chosen will depend upon the composition of the stand. Where even-aged stands of one species are studied, probably two representative trees of the dominant and codominant classes will be sufficient. In all-aged stands, at least three trees of various ages above reproduction should be included and two sets of such trees if the stand contains more than one prominent species, or if the site is being studied from the standpoint of more than one species. In studies of reproduction conditions, the smallest seedlings available should be under observation.

In these external observations, Forest Service Form 416 may be used as a guide, since it covers comprehensively the ordinary phenological observations. A reduced copy of this form may well be kept in the field notebook, and the field observations may be given in the form of numbers corresponding to the captions of the "Phenological Observations" form. For example, "1" would be used to indicate that buds were beginning to swell.

As has been said, ocular observations on these common phenomena of growth, especially at the actual beginning of tree growth in the spring and its termination in the fall, are too crude. Some method of measuring and recording the actual growth from day to day is required. A number of auxometers might be mentioned, but a meter really adapted to plants in the field, and especially the exposed swaying tops of trees, has not been produced, so far as the writers know. There is unlimited field here for invention.

Form 416.

[U. S. Department of Agriculture, Forest Service.]

PHENOLOGICAL OBSERVATIONS.

Species _____

Period covered by observations _____

Name of observer _____

Residence _____

(State.)

(County.)

(Town.)

General character of country.—*Mountains; foothills; plains; river valley; seacoast.*

Situation of trees.—*Level; slope (north, east, west, south); hilltop; river bottom; soil (sandy, clayey, heavy, light, deep, shallow, moist, dry); forest; open ground; park; street.*

(Please check the words which apply to your particular locality and to the trees observed.)

Approximate elevation above sea level _____

Location of nearest Weather Bureau station _____

State if season was wet or dry, early or late, etc. _____

	Date.		Date.
1. <i>Swelling of buds</i> -----		9. <i>End of leaf falling</i> -----	
2. <i>Bursting of buds</i> -----		10. <i>Beginning of seed ripening</i> -----	
3. <i>Beginning of leafing out</i> -----		11. <i>General seed ripening</i> -----	
4. <i>General leafing out</i> -----		12. <i>Beginning of seed falling</i> -----	
5. <i>Beginning of blossoming</i> -----		13. <i>End of seed falling</i> -----	
6. <i>General blossoming</i> -----		14. <i>Quantity of seed</i> -----	
7. <i>Change in color of foliage</i> -----		15. <i>Quality of seed</i> -----	
8. <i>Beginning of leaf falling</i> -----			
General remarks-----			

Instructions on back of this form should be followed strictly.

Under the name "dendograph" McDougal²² has designed a new instrument for measuring and recording the diameter growth of tree stems. This instrument is being thoroughly tried out. It will probably be a very valuable adjunct. It is not simple in construction or operation, however, and will always be too expensive to be extensively used. It would seem that a beginning must be made in a more simple way, perhaps through circumferential measurements, even though a number of complicating factors must be taken into account, such as the expansion of the tree and of the tape with increased temperatures.

INTERNAL OR PHYSIOLOGICAL OBSERVATIONS.

Although the forester is prone to think of growth as the major reaction of interest, it is entirely possible that there may be positive gain in studying the more fundamental reactions which lead up to growth. For example, in the conifers, the outward evidences of growth may disappear by midsummer, so far as height accretion is concerned: yet diameter growth continues longer, and this period of relative inactivity is of great importance in accumulating a reserve for the effort of the following season. Is it not logical, therefore, that the growing season for trees should be considered to be the entire period in which materials for growth are being produced?

Again, while growth is a large factor when competition begins, the critical conditions which have the greatest bearing on the success of the individual and species, and thereby affect most acutely the character of the plant formation, may, in the case of all perennial plants, be encountered not in the growing season but in the dead of winter. Through neglect of this period erroneous conclusions may again be reached as to the importance of various conditions in building up the plant formation.

It should therefore be most desirable to be able to determine the physiological conditions of the plant frequently in order that its reaction to every change in environment may be followed. The

²² MacDougal, D. T. *Growth in Trees*. Pub. 397, Carnegie Inst. Washington, 1921.

writers know of no single method or basic method of following these reactions which promises more than the method of following the plant's condition by frequent observations on the osmotic pressure or sap density. In the case of trees, the termini should of course be studied, but it is probable that valuable supplemental data can be obtained at one or two points along the stem and on side branches. Through this method, with any individual tree, it may be possible to depict the sudden influx of sap in the spring, which precedes the first growth; the gradual increase in carbohydrates as the new tissues continue to function, and temporary changes due to water supply and water loss. Possibly the end point of the season's photo-synthetic activity may be found, if there is any; the same method will show the changes which the tree undergoes through the winter. In addition to osmotic pressures, the starch content of leaves should be examined from time to time. It is self-evident that these data can only be interpreted when correlated with observations on both the soil and atmospheric conditions.

A method which would show the rate at which the tree is being supplied with water would be a valuable adjunct to the above; but no attempt of this nature is known, beyond transpiration studies. It is possible, however, that a means may be devised by which this rate may be directly determined. There is room for a great deal of development in these lines.

FIELD OBSERVATIONS, PHOTOGRAPHS, AND MAPS.

The "Daily Observations" form in the series for climatological studies, intended for field observations, is thought to be adapted to universal use. It is of a size to fit Forest Service loose-leaf notebooks, 6 $\frac{7}{8}$ by 4 inches. It contains lines for all factors on which regular observations are likely to be taken. It has five vertical columns, which may be used for five stations visited consecutively on the same day, or for a single station visited for five consecutive observations. In the first instance the numbers of the stations would be stamped at the heads of the several columns and the date would be stamped at the bottom. In the second instance the days of the month would be stamped at the heads of the several columns and the month and year at the foot of the form. In either case the exact time of observation should be entered in the second line of each column. Since observations at completely equipped stations may take from 10 to 20 minutes, the time entered for such stations should be, as nearly as possible, the time of reading current temperature and anemometer, these conditions being subject to considerable changes in a few minutes.

Each point chosen as a site for ecological study should, in addition to a complete description²³ of the features which may influence soil qual-

²³ The "Description" form is suggestive.

ity, insolation, wind exposure, etc., be witnessed by photographs and topographic map. The former should be taken from as many positions as possible to show the general position of the station with respect to topographic features, to show the position of the trees which may influence atmospheric factors, to furnish a map of the canopy (by vertical view) which affects the insolation at the ground, and finally to show in detail the nature of the ground and ground cover. The view of the canopy should be taken as nearly as possible from the position which will be occupied by solar apparatus and evaporimeter.

The local topographic map should be made on a scale adequate to show in detail the immediate surroundings and those which are close enough to have appreciable effect on insolation, wind velocity, etc. Especially when two or more stations in close proximity, but different presumably in some essential aspect, are being studied, should the map be made full enough to bring out clearly the contrast which exists in conditions. In such cases a joint map for the several stations may well be used. Such maps should, if possible, be restricted to the size of the tabulating forms used.

Form 1.

[U. S. Forest Service, Physical Survey.]

DESCRIPTION OF OBSERVATION POINT, LIMITED AREA, TREE ENVIRONMENT.

Project _____

Station No. _____	Area involved _____
Forest type _____	Absolute elevation _____
Permanent sample plot No. _____	Block No _____
National Forest _____	Nearest post office _____
County _____	State _____
Legal location _____	Exact location _____

TOPOGRAPHIC FEATURES.

Aspect _____	Gradient _____
Distance from ridge _____	Distance from channel _____
Elevation above water _____	Wind exposure _____
Air drainage conditions _____	
Elevation of horizon to east _____; west _____; north _____; south _____	
Character of topography _____	

FOREST ENVIRONMENT.

Distance of nearest trees to north _____; east _____; south _____; west _____	
Age of trees _____	Height _____
Diameter _____	Trees per acre _____
Stand, feet b. m. _____	Stand, cubic feet _____
Growth rate; height, diameter, or cubic feet per A. A. _____	
Shading, amount _____	From trees on _____
Light at the ground, per cent. _____	Determined by _____

Summary of forest conditions affecting reproduction or the special tree under observation, as to shading, exhaustion of soil moisture, influence of herbaceous vegetation, underbrush, etc.-----

Description of the special tree under observation as to size, growth, vigor, and reproductive capacity;-----

SOIL CHARACTER AND MOISTURE SUPPLY.

Depth of litter----- Character-----
Depth of humus----- Present moisture-----
Penetration of humus in mineral soil as shown by color, inches-----
Character of subsoil, distinguished from soil-----
Total depth of soil permeable to roots, inches-----
Amount and kind of rock fragments in soil-----
Character of impermeable substratum-----
Soil origin (in situ, colluvial, alluvial, or eolian, and from what rocks)-----

Composition and class-----
Drainage----- Present moisture-----

REFERENCES.

Maps-----
Reports-----
Photographs-----
Environmental conditions measured-----
Moisture samples----- Samples for analysis-----
Soil analyses filed-----
Observations by----- (date)-----

APPENDICES.

APPENDIX A.

VAPOR PRESSURE TABLES—WAGON WHEEL GAP, COLORADO.

The accompanying table for obtaining vapor pressures from reading of the dry and wet bulb thermometers was computed by Mr. B. C. Kadel for a pressure of 21.42 inches, from the Ferrel psychrometric formula used by the Weather Bureau:

$$e = e' - 0.000367B(t - t') \left(1 + \frac{t' - 32}{1,571} \right)$$

in which t and t' are the temperatures of the dry and wet bulb thermometers in degrees Fahrenheit, B is the barometric pressure in inches, e' is the saturation pressure of aqueous vapor at the temperature t' of the wet bulb, and e is the vapor pressure corresponding to the thermometer readings. The constants of the formula were determined by Profs. Hazen and Marvin, of the United States Weather Bureau.

TABLE 8. — *Values of* $0.000367 P \left(1 + \frac{t' - 32}{1,571} \right)$ *when* $P = 21.42$ *inches, log.* $0.000367 P = 7.89549$.

t'	$1 + \frac{t' - 32}{1,571}$	log.	+7.89549	Product.
—35.....	0.95736	9.98107	7.87656	0.007526
—30.....	.96054	9.98252	7.87801	.007551
—25.....	.96372	9.98395	7.87944	.007576
—20.....	.96690	9.98538	7.88087	.007601
—15.....	.97008	.98681	.88230	.007626
—10.....	.97327	.98824	.88373	.007651
—5.....	.97645	.98965	.88514	.007676
Zero.....	.97963	.99106	.88655	.007701
5.....	.98282	.99248	.88797	.007726
10.....	.98600	.99388	.88937	.007751
15.....	.98917	.99527	.89076	.007776
20.....	.99236	.99667	.89216	.007801
25.....	.99554	.99806	.89355	.007826
30.....	.99873	.99945	.89494	.007851
35.....	1.00191	.00083	.89632	.007876
40.....	1.00509	.00221	.89770	.007901
45.....	1.00827	.00358	.89907	.007926
50.....	1.01146	.00495	.90044	.007951
55.....	1.01464	.00632	.90181	.007976
60.....	1.01782	.00767	.90316	.008001
65.....	1.02101	.00903	.90452	.008026
70.....	1.02418	.01038	.90587	.008051
75.....	1.02737	.01173	.90722	.008076
80.....	1.03055	.01307	.90856	.008101
85.....	1.03373	.01441	.90990	.008126
90.....	1.03692	.01575	.91124	.008152

TABLE 9.—Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F.WET BULB -16° TO -8° .

Wet bulb.	0.0	1.0	2.0	Wet bulb.	0.0	1.0	2.0	3.0	Proportional parts.	
									Degrees.	Inches.
-16.0.....	0.0159	0.0083	0.0007	-12.0.....	0.0199	0.0123	0.0046	.....	0.1	0.0008
-15.9.....	.0160	.0084	.0008	-11.9.....	.0200	.0124	.0047	.....	.2	.0015
-15.8.....	.0160	.0084	.0008	-11.8.....	.0201	.0125	.0048	.....	.3	.0023
-15.7.....	.0161	.0085	.0009	-11.7.....	.0202	.0126	.0049	.....	.4	.0031
-15.6.....	.0162	.0086	.0010	-11.6.....	.0203	.0127	.0050	.....	.5	.0038
-15.5.....	.0163	.0087	.0011	-11.5.....	.0204	.0128	.0051	.....	.6	.0046
-15.4.....	.0164	.0088	.0011	-11.4.....	.0206	.0130	.0053	.....	.7	.0053
-15.3.....	.0165	.0089	.0012	-11.3.....	.0207	.0131	.0054	.....	.8	.0061
-15.2.....	.0166	.0090	.0013	-11.2.....	.0208	.0132	.0055	.....	.9	.0069
-15.1.....	.0167	.0091	.0014	-11.1.....	.0209	.0133	.0056	.....		
-15.0.....	.0168	.0092	.0015	-11.0.....	.0210	.0134	.0057	.....		
-14.9.....	.0169	.0093	.0016	-10.9.....	.0212	.0136	.0059	.....		
-14.8.....	.0170	.0094	.0017	-10.8.....	.0213	.0137	.0060	.....		
-14.7.....	.0171	.0095	.0018	-10.7.....	.0214	.0138	.0061	.....		
-14.6.....	.0172	.0096	.0019	-10.6.....	.0215	.0139	.0062	.....		
-14.5.....	.0173	.0097	.0020	-10.5.....	.0216	.0140	.0064	.....		
-14.4.....	.0174	.0098	.0021	-10.4.....	.0217	.0141	.0065	.....		
-14.3.....	.0175	.0099	.0022	-10.3.....	.0218	.0142	.0066	.....		
-14.2.....	.0176	.0100	.0023	-10.2.....	.0220	.0143	.0067	.....		
-14.1.....	.0177	.0101	.0024	-10.1.....	.0221	.0144	.0068	.....		
-14.0.....	.0178	.0102	.0025	-10.0.....	.0222	.0145	.0069	.....		
-13.9.....	.0179	.0103	.0026	-9.9.....	.0223	.0146	.0070	.....		
-13.8.....	.0180	.0104	.0027	-9.8.....	.0224	.0147	.0071	.....		
-13.7.....	.0181	.0105	.0028	-9.7.....	.0226	.0149	.0073	.....		
-13.6.....	.0182	.0106	.0029	-9.6.....	.0227	.0150	.0074	.....		
-13.5.....	.0183	.0107	.0030	-9.5.....	.0228	.0151	.0075	.....		
-13.4.....	.0184	.0108	.0031	-9.4.....	.0229	.0152	.0076	.....		
-13.3.....	.0185	.0109	.0032	-9.3.....	.0230	.0153	.0077	.....		
-13.2.....	.0186	.0110	.0033	-9.2.....	.0232	.0154	.0079	.....		
-13.1.....	.0187	.0111	.0034	-9.1.....	.0233	.0155	.0080	.....		
-13.0.....	.0188	.0112	.0035	-9.0.....	.0234	.0157	.0081	0.0004		
-12.9.....	.0189	.0113	.0036	-8.9.....	.0236	.0159	.0083	.0006		
-12.8.....	.0190	.0114	.0037	-8.8.....	.0237	.0160	.0084	.0007		
-12.7.....	.0191	.0115	.0038	-8.7.....	.0238	.0161	.0085	.0008		
-12.6.....	.0192	.0116	.0039	-8.6.....	.0239	.0162	.0086	.0009		
-12.5.....	.0193	.0117	.0040	-8.5.....	.0240	.0163	.0087	.0010		
-12.4.....	.0194	.0118	.0041	-8.4.....	.0242	.0165	.0089	.0012		
-12.3.....	.0195	.0119	.0042	-8.3.....	.0243	.0166	.0090	.0013		
-12.2.....	.0196	.0120	.0043	-8.2.....	.0244	.0167	.0091	.0014		
-12.1.....	.0197	.0121	.0044	-8.1.....	.0246	.0169	.0093	.0016		
-12.0.....	.0199	.0123	.0046	-8.0.....	.0247	.0170	.0094	.0017		

WET BULB -8° TO -0° .

Wet bulb.	0.0	1.0	2.0	3.0	Wet bulb.	0.0	1.0	2.0	3.0	4.0
-8.0.....	0.0247	0.0170	0.0094	0.0017	-4.0.....	0.0307	0.0236	0.0153	0.0077	0.0000
-7.9.....	.0248	.0171	.0095	.0018	-3.9.....	.0309	.0232	.0155	.0079	.0002
-7.8.....	.0249	.0172	.0096	.0019	-3.8.....	.0311	.0234	.0157	.0081	.0004
-7.7.....	.0250	.0173	.0097	.0020	-3.7.....	.0313	.0236	.0159	.0083	.0006
-7.6.....	.0252	.0175	.0099	.0022	-3.6.....	.0315	.0238	.0161	.0084	.0008
-7.5.....	.0254	.0177	.0101	.0024	-3.5.....	.0316	.0239	.0162	.0085	.0009
-7.4.....	.0255	.0178	.0102	.0025	-3.4.....	.0318	.0241	.0164	.0087	.0011
-7.3.....	.0256	.0179	.0103	.0026	-3.3.....	.0320	.0243	.0166	.0089	.0013
-7.2.....	.0257	.0180	.0104	.0027	-3.2.....	.0322	.0245	.0168	.0091	.0015
-7.1.....	.0258	.0181	.0105	.0028	-3.1.....	.0324	.0247	.0170	.0093	.0017
-7.0.....	.0260	.0183	.0107	.0030	-3.0.....	.0325	.0248	.0177	.0094	.0018
-6.9.....	.0262	.0185	.0109	.0032	-2.9.....	.0327	.0250	.0173	.0096	.0020
-6.8.....	.0263	.0186	.0110	.0033	-2.8.....	.0329	.0252	.0175	.0098	.0022
-6.7.....	.0264	.0187	.0111	.0034	-2.7.....	.0330	.0253	.0176	.0099	.0023
-6.6.....	.0266	.0189	.0113	.0036	-2.6.....	.0332	.0255	.0178	.0101	.0024
-6.5.....	.0268	.0191	.0115	.0037	-2.5.....	.0334	.0257	.0180	.0103	.0026
-6.4.....	.0269	.0192	.0116	.0038	-2.4.....	.0336	.0259	.0182	.0105	.0028
-6.3.....	.0270	.0193	.0117	.0039	-2.3.....	.0338	.0261	.0184	.0107	.0030
-6.2.....	.0272	.0195	.0119	.0041	-2.2.....	.0340	.0263	.0186	.0109	.0032
-6.1.....	.0274	.0197	.0121	.0043	-2.1.....	.0342	.0265	.0188	.0111	.0034
-6.0.....	.0275	.0198	.0122	.0044	-2.0.....	.0344	.0267	.0190	.0113	.0036

TABLE 9.—Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F—Continued.WET BULB -8° TO -0° —Continued.

Wet bulb.	0.0	1.0	2.0	3.0	Wet bulb.	0.0	1.0	2.0	3.0	4.0
-5.9.....	.0276	.0199	.0123	.0046	-1.9.....	.0346	.0269	.0192	.0115	.0038
-5.8.....	.0278	.0201	.0125	.0048	-1.8.....	.0347	.0270	.0193	.0116	.0039
-5.7.....	.0280	.0203	.0126	.0050	-1.7.....	.0349	.0272	.0195	.0118	.0041
-5.6.....	.0281	.0204	.0127	.0051	-1.6.....	.0351	.0274	.0197	.0120	.0043
-5.5.....	.0282	.0205	.0128	.0052	-1.5.....	.0353	.0276	.0199	.0122	.0045
-5.4.....	.0284	.0207	.0130	.0054	-1.4.....	.0355	.0278	.0201	.0124	.0047
-5.3.....	.0286	.0209	.0132	.0056	-1.3.....	.0357	.0280	.0203	.0126	.0049
-5.2.....	.0287	.0211	.0133	.0057	-1.2.....	.0359	.0282	.0205	.0128	.0051
-5.1.....	.0289	.0213	.0135	.0059	-1.1.....	.0361	.0284	.0207	.0130	.0053
-5.0.....	.0291	.0214	.0137	.0061	-1.0.....	.0363	.0286	.0209	.0132	.0055
-4.9.....	.0292	.0215	.0138	.0062	-0.9.....	.0365	.0288	.0211	.0134	.0057
-4.8.....	.0294	.0217	.0140	.0064	-0.8.....	.0367	.0290	.0213	.0136	.0059
-4.7.....	.0296	.0219	.0142	.0066	-0.7.....	.0369	.0292	.0215	.0138	.0061
-4.6.....	.0297	.0220	.0143	.0067	-0.6.....	.0371	.0294	.0218	.0140	.0063
-4.5.....	.0299	.0222	.0145	.0069	-0.5.....	.0373	.0296	.0220	.0142	.0065
-4.4.....	.0301	.0224	.0147	.0071	-0.4.....	.0375	.0298	.0222	.0144	.0067
-4.3.....	.0302	.0225	.0148	.0072	-0.3.....	.0377	.0300	.0224	.0146	.0069
-4.2.....	.0304	.0227	.0150	.0074	-0.2.....	.0379	.0302	.0226	.0148	.0071
-4.1.....	.0306	.0229	.0152	.0076	-0.1.....	.0381	.0304	.0228	.0150	.0073
-4.0.....	.0307	.0230	.0153	.0077	-0.0.....	.0383	.0306	.0230	.0152	.0075

WET BULB 0° TO 4° .

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	Proportional parts.	
								Degrees.	Inches.
0.0.....	0.0383	0.0366	0.0229	0.0152	.....	.....	.....	0.1	0.0008
0.1.....	.0385	.0368	.0231	.0154	.....	.....	.....	.2	.0015
0.2.....	.0387	.0310	.0233	.0156	.....	.....	.....	.3	.0023
0.3.....	.0389	.0312	.0235	.0158	.....	.....	.....	.4	.0031
0.4.....	.0391	.0314	.0237	.0160	.....	.....	.....	.5	.0039
0.5.....	.0392	.0316	.0239	.0162	.....	.....	.....	.6	.0046
0.6.....	.0394	.0318	.0241	.0164	.....	.....	.....	.7	.0054
0.7.....	.0396	.0320	.0243	.0166	.....	.....	.....	.8	.0061
0.8.....	.0398	.0322	.0245	.0168	.....	.....	.....	.9	.0069
0.9.....	.0400	.0324	.0247	.0170	.....	.....	.....		
1.0.....	.0403	.0326	.0249	.0172	0.0095	.....	.....		
1.1.....	.0405	.0328	.0251	.0174	.0096	.....	.....		
1.2.....	.0407	.0330	.0253	.0176	.0098	.....	.....		
1.3.....	.0409	.0332	.0255	.0178	.0100	.....	.....		
1.4.....	.0411	.0334	.0257	.0180	.0102	.....	.....		
1.5.....	.0413	.0336	.0259	.0182	.0104	.....	.....		
1.6.....	.0415	.0338	.0261	.0184	.0106	.....	.....		
1.7.....	.0417	.0340	.0263	.0186	.0108	.....	.....		
1.8.....	.0419	.0342	.0265	.0188	.0110	.....	.....		
1.9.....	.0421	.0344	.0267	.0190	.0112	.....	.....		
2.0.....	.0423	.0346	.0269	.0191	.0114	0.0037	.....		
2.1.....	.0426	.0348	.0272	.0194	.0116	.0040	.....		
2.2.....	.0428	.0351	.0274	.0196	.0119	.0042	.....		
2.3.....	.0430	.0352	.0276	.0198	.0120	.0044	.....		
2.4.....	.0431	.0354	.0277	.0199	.0122	.0045	.....		
2.5.....	.0434	.0356	.0280	.0202	.0124	.0048	.....		
2.6.....	.0436	.0359	.0282	.0204	.0127	.0050	.....		
2.7.....	.0438	.0361	.0284	.0206	.0129	.0052	.....		
2.8.....	.0440	.0363	.0286	.0208	.0131	.0054	.....		
2.9.....	.0442	.0365	.0288	.0210	.0133	.0056	.....		
3.0.....	.0444	.0367	.0290	.0212	.0135	.0058	.....		
3.1.....	.0446	.0369	.0292	.0214	.0137	.0060	.....		
3.2.....	.0449	.0372	.0295	.0217	.0140	.0063	.....		
3.3.....	.0451	.0374	.0297	.0219	.0142	.0065	.....		
3.4.....	.0453	.0376	.0299	.0221	.0144	.0067	.....		
3.5.....	.0456	.0379	.0302	.0224	.0147	.0070	.....		
3.6.....	.0458	.0381	.0304	.0226	.0149	.0072	.....		
3.7.....	.0460	.0383	.0306	.0228	.0151	.0074	.....		
3.8.....	.0462	.0385	.0308	.0230	.0153	.0076	.....		
3.9.....	.0464	.0387	.0310	.0232	.0155	.0078	.....		
4.0.....	.0467	.0390	.0313	.0235	.0158	.0081	0.0004		

TABLE 9.—Vapor pressure. inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F—Continued.

WET BULB 4° TO 8°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	Proportional parts.	
									Degrees.	Inches.
4.0.....	0.0467	0.0390	0.0313	0.0235	0.0158	0.0081	0.0004		0.1	0.0008
4.1.....	.0470	.0393	.0316	.0238	.0161	.0084	.0007		.2	.0015
4.2.....	.0472	.0395	.0318	.0240	.0163	.0086	.0009		.3	.0023
4.3.....	.0474	.0397	.0320	.0242	.0165	.0088	.0011		.4	.0031
4.4.....	.0476	.0399	.0322	.0244	.0167	.0090	.0013		.5	.0039
4.5.....	.0478	.0401	.0324	.0246	.0169	.0092	.0015		.6	.0046
4.6.....	.0481	.0404	.0327	.0249	.0172	.0095	.0018		.7	.0054
4.7.....	.0484	.0407	.0330	.0251	.0175	.0098	.0021		.8	.0062
4.8.....	.0486	.0409	.0332	.0253	.0177	.0100	.0023		.9	.0069
4.9.....	.0488	.0411	.0334	.0256	.0180	.0103	.0026			
5.0.....	.0491	.0414	.0336	.0259	.0182	.0106	.0027			
5.1.....	.0493	.0416	.0338	.0261	.0184	.0108	.0029			
5.2.....	.0495	.0418	.0340	.0263	.0186	.0110	.0031			
5.3.....	.0498	.0421	.0343	.0266	.0189	.0113	.0034			
5.4.....	.0500	.0423	.0345	.0268	.0190	.0115	.0036			
5.5.....	.0502	.0425	.0347	.0270	.0192	.0117	.0038			
5.6.....	.0505	.0428	.0350	.0273	.0195	.0120	.0041			
5.7.....	.0508	.0431	.0353	.0276	.0198	.0123	.0044			
5.8.....	.0510	.0433	.0355	.0278	.0200	.0125	.0046			
5.9.....	.0512	.0435	.0357	.0280	.0203	.0126	.0048			
6.0.....	.0515	.0438	.0360	.0283	.0206	.0128	.0051			
6.1.....	.0518	.0441	.0363	.0286	.0209	.0131	.0054			
6.2.....	.0520	.0443	.0365	.0288	.0211	.0133	.0056			
6.3.....	.0523	.0446	.0368	.0291	.0214	.0136	.0059			
6.4.....	.0526	.0449	.0371	.0294	.0217	.0139	.0062			
6.5.....	.0528	.0451	.0373	.0296	.0219	.0141	.0064			
6.6.....	.0531	.0454	.0376	.0299	.0222	.0144	.0067			
6.7.....	.0534	.0457	.0379	.0302	.0225	.0147	.0070			
6.8.....	.0536	.0459	.0381	.0304	.0227	.0150	.0072			
6.9.....	.0539	.0462	.0384	.0307	.0230	.0153	.0075			
7.0.....	.0542	.0465	.0387	.0310	.0233	.0155	.0078			
7.1.....	.0544	.0467	.0389	.0312	.0236	.0157	.0080			
7.2.....	.0547	.0470	.0392	.0315	.0239	.0160	.0083			
7.3.....	.0550	.0473	.0395	.0318	.0242	.0163	.0086			
7.4.....	.0553	.0476	.0398	.0321	.0245	.0166	.0089			
7.5.....	.0556	.0479	.0401	.0324	.0248	.0169	.0092			
7.6.....	.0558	.0481	.0403	.0326	.0250	.0171	.0094			
7.7.....	.0561	.0484	.0406	.0329	.0253	.0174	.0097			
7.8.....	.0564	.0487	.0409	.0332	.0256	.0177	.0100			
7.9.....	.0567	.0490	.0412	.0335	.0259	.0180	.0103			
8.0.....	.0570	.0493	.0415	.0338	.0262	.0184	.0106	0.0028		

WET BULB 8° TO 12°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	Proportional parts.	
											Deg.	Ins.
8.0....	0.0570	0.0492	0.0415	0.0338	0.0260	0.0183	0.0106	0.0028			0.1	0.0008
8.1....	.0573	.0495	.0418	.0341	.0263	.0186	.0109	.0031			.2	.0016
8.2....	.0576	.0498	.0421	.0344	.0266	.0189	.0112	.0034			.3	.0023
8.3....	.0579	.0501	.0424	.0347	.0269	.0192	.0115	.0037			.4	.0031
8.4....	.0582	.0504	.0427	.0350	.0272	.0195	.0118	.0040			.5	.0039
8.5....	.0584	.0506	.0429	.0352	.0274	.0197	.0120	.0043			.6	.0047
8.6....	.0587	.0509	.0432	.0355	.0277	.0200	.0123	.0046			.7	.0054
8.7....	.0590	.0512	.0435	.0358	.0280	.0203	.0126	.0049			.8	.0062
8.8....	.0594	.0514	.0439	.0362	.0284	.0207	.0130	.0052			.9	.0070
8.9....	.0597	.0518	.0442	.0365	.0287	.0210	.0132	.0055				
9.0....	.0600	.0523	.0445	.0368	.0290	.0213	.0135	.0058				
9.1....	.0603	.0526	.0448	.0371	.0293	.0216	.0138	.0061				
9.2....	.0606	.0529	.0451	.0374	.0296	.0219	.0141	.0064				
9.3....	.0609	.0532	.0454	.0377	.0299	.0222	.0144	.0067				
9.4....	.0612	.0535	.0457	.0380	.0302	.0225	.0147	.0070				
9.5....	.0615	.0538	.0461	.0383	.0306	.0228	.0151	.0073				
9.6....	.0618	.0541	.0464	.0386	.0309	.0231	.0154	.0076				
9.7....	.0622	.0545	.0468	.0390	.0313	.0235	.0158	.0080				
9.8....	.0625	.0548	.0471	.0393	.0316	.0238	.0161	.0083				
9.9....	.0628	.0550	.0474	.0396	.0318	.0240	.0164	.0086				
10.0....	.0631	.0553	.0476	.0398	.0321	.0243	.0166	.0088	.0011			

TABLE 9.—Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F—Continued.

WET BULB 8° TO 12°—Continued.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	Proportional parts.
10.1...	.0634	.0556	.0479	.0401	.0324	.0246	.0169	.0091	.0014	-----	
10.2...	.0638	.0560	.0483	.0405	.0328	.0250	.0173	.0095	.0018	-----	
10.3...	.0641	.0563	.0486	.0408	.0331	.0253	.0176	.0098	.0021	-----	
10.4...	.0644	.0566	.0489	.0411	.0334	.0256	.0179	.0101	.0024	-----	
10.5...	.0648	.0570	.0493	.0415	.0338	.0260	.0183	.0105	.0027	-----	
10.6...	.0651	.0573	.0496	.0418	.0341	.0263	.0186	.0108	.0030	-----	
10.7...	.0654	.0576	.0499	.0421	.0344	.0266	.0189	.0111	.0034	-----	
10.8...	.0657	.0579	.0502	.0424	.0347	.0269	.0192	.0114	.0038	-----	
10.9...	.0661	.0583	.0506	.0428	.0351	.0273	.0196	.0118	.0041	-----	
11.0...	.0665	.0587	.0510	.0432	.0355	.0277	.0200	.0122	.0045	-----	
11.1...	.0668	.0590	.0513	.0435	.0358	.0280	.0203	.0125	.0048	-----	
11.2...	.0671	.0593	.0516	.0438	.0361	.0283	.0206	.0128	.0051	-----	
11.3...	.0674	.0596	.0519	.0441	.0364	.0286	.0210	.0131	.0054	-----	
11.4...	.0678	.0600	.0523	.0445	.0368	.0290	.0214	.0135	.0058	-----	
11.5...	.0682	.0604	.0527	.0449	.0372	.0294	.0217	.0139	.0062	-----	
11.6...	.0685	.0607	.0530	.0453	.0375	.0297	.0220	.0142	.0065	-----	
11.7...	.0688	.0610	.0533	.0456	.0378	.0300	.0223	.0145	.0068	-----	
11.8...	.0692	.0614	.0537	.0460	.0382	.0304	.0227	.0149	.0071	-----	
11.9...	.0696	.0618	.0541	.0463	.0386	.0308	.0230	.0153	.0074	-----	
12.0...	.0699	.0621	.0544	.0466	.0389	.0311	.0233	.0156	.0078	0.0001	

WET BULB 12° TO 16°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	Proportional parts.	
												Deg.	Ins.
12.0....	0.0699	0.0621	0.0544	0.0466	0.0389	0.0311	0.0233	0.0156	0.0078	0.0001	-----	0.1	0.0008
12.1....	.0702	.0624	.0547	.0469	.0392	.0314	.0236	.0159	.0081	.0004	-----	.2	.0015
12.2....	.0706	.0628	.0551	.0473	.0395	.0318	.0240	.0163	.0085	.0008	-----	.3	.0023
12.3....	.0710	.0632	.0555	.0477	.0399	.0322	.0244	.0167	.0089	.0012	-----	.4	.0031
12.4....	.0713	.0635	.0558	.0480	.0402	.0325	.0247	.0170	.0092	.0015	-----	.5	.0039
12.5....	.0716	.0638	.0561	.0483	.0405	.0328	.0250	.0173	.0095	.0018	-----	.6	.0047
12.6....	.0720	.0642	.0565	.0487	.0409	.0332	.0254	.0176	.0099	.0021	-----	.7	.0054
12.7....	.0724	.0646	.0569	.0491	.0413	.0336	.0258	.0180	.0103	.0025	-----	.8	.0062
12.8....	.0728	.0650	.0573	.0495	.0417	.0340	.0262	.0184	.0107	.0029	-----	.9	.0070
12.9....	.0732	.0654	.0577	.0499	.0421	.0344	.0266	.0188	.0111	.0033	-----		
13.0....	.0735	.0657	.0580	.0502	.0424	.0347	.0269	.0191	.0114	.0036	-----		
13.1....	.0738	.0660	.0583	.0505	.0427	.0350	.0272	.0194	.0117	.0039	-----		
13.2....	.0742	.0664	.0587	.0509	.0431	.0354	.0276	.0198	.0120	.0043	-----		
13.3....	.0746	.0668	.0591	.0513	.0435	.0358	.0280	.0202	.0124	.0047	-----		
13.4....	.0750	.0672	.0595	.0517	.0439	.0362	.0284	.0206	.0128	.0051	-----		
13.5....	.0754	.0676	.0599	.0521	.0443	.0366	.0288	.0210	.0132	.0055	-----		
13.6....	.0757	.0679	.0602	.0524	.0446	.0369	.0291	.0213	.0135	.0058	-----		
13.7....	.0761	.0683	.0606	.0528	.0450	.0372	.0295	.0217	.0139	.0062	-----		
13.8....	.0765	.0687	.0610	.0532	.0454	.0376	.0299	.0221	.0143	.0066	-----		
13.9....	.0768	.0690	.0613	.0535	.0457	.0379	.0302	.0224	.0147	.0069	-----		
14.0....	.0772	.0694	.0617	.0539	.0461	.0383	.0306	.0228	.0150	.0073	-----		
14.1....	.0776	.0698	.0621	.0543	.0465	.0387	.0310	.0232	.0154	.0077	-----		
14.2....	.0780	.0702	.0625	.0547	.0469	.0391	.0314	.0236	.0158	.0081	-----		
14.3....	.0784	.0706	.0629	.0551	.0473	.0395	.0318	.0240	.0162	.0083	-----		
14.4....	.0787	.0709	.0632	.0554	.0476	.0398	.0321	.0243	.0165	.0086	-----		
14.5....	.0790	.0712	.0635	.0557	.0479	.0401	.0324	.0246	.0168	.0090	-----		
14.6....	.0794	.0716	.0639	.0561	.0483	.0405	.0327	.0250	.0172	.0094	-----		
14.7....	.0798	.0720	.0642	.0565	.0487	.0409	.0331	.0254	.0176	.0098	-----		
14.8....	.0802	.0724	.0646	.0569	.0491	.0413	.0335	.0258	.0180	.0102	-----		
14.9....	.0806	.0728	.0650	.0573	.0495	.0417	.0339	.0262	.0184	.0106	-----		
15.0....	.0810	.0732	.0654	.0577	.0499	.0421	.0343	.0266	.0188	.0110	0.0034		
15.1....	.0814	.0736	.0658	.0581	.0503	.0425	.0347	.0270	.0192	.0114	.0038		
15.2....	.0818	.0740	.0662	.0585	.0507	.0429	.0351	.0274	.0196	.0118	.0042		
15.3....	.0822	.0744	.0666	.0589	.0511	.0433	.0355	.0278	.0200	.0122	.0046		
15.4....	.0826	.0748	.0670	.0593	.0515	.0437	.0359	.0282	.0204	.0126	.0050		
15.5....	.0830	.0752	.0674	.0597	.0519	.0441	.0363	.0285	.0208	.0130	.0053		
15.6....	.0834	.0756	.0678	.0601	.0523	.0445	.0367	.0289	.0212	.0134	.0057		
15.7....	.0838	.0760	.0682	.0605	.0527	.0449	.0371	.0293	.0216	.0138	.0060		
15.8....	.0842	.0764	.0686	.0609	.0531	.0453	.0375	.0297	.0220	.0142	.0064		
15.9....	.0846	.0768	.0690	.0613	.0535	.0457	.0379	.0301	.0224	.0146	.0068		
16.0....	.0850	.0772	.0694	.0617	.0539	.0461	.0383	.0305	.0228	.0150	.0072		

TABLE 9.—*Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb (T.—t'), °F—Continued.*

WET BULB 16° TO 20°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
16.0.....	0.0850	0.0772	0.0694	0.0617	0.0539	0.0461	0.0383	0.0305	0.0228	0.0150	0.0072
16.1.....	.0854	.0776	.0698	.0621	.0543	.0465	.0387	.0309	.0232	.0154	.....
16.2.....	.0857	.0779	.0701	.0625	.0546	.0468	.0390	.0312	.0236	.0157	.....
16.3.....	.0862	.0784	.0706	.0629	.0551	.0473	.0395	.0317	.0240	.0162	.....
16.4.....	.0866	.0788	.0710	.0633	.0555	.0477	.0399	.0321	.0244	.0166	.....
16.5.....	.0870	.0792	.0714	.0637	.0559	.0481	.0403	.0325	.0248	.0169	.....
16.6.....	.0874	.0796	.0718	.0641	.0563	.0485	.0407	.0329	.0252	.0173	.....
16.7.....	.0878	.0800	.0722	.0645	.0567	.0489	.0411	.0333	.0256	.0177	.....
16.8.....	.0882	.0804	.0726	.0649	.0571	.0493	.0415	.0337	.0260	.0181	.....
16.9.....	.0886	.0808	.0730	.0653	.0575	.0497	.0419	.0341	.0264	.0185	.....
17.0.....	.0891	.0813	.0735	.0657	.0580	.0502	.0424	.0346	.0268	.0190	.0112
17.1.....	.0895	.0817	.0739	.0661	.0584	.0506	.0428	.0350	.0272	.0194	.0116
17.2.....	.0899	.0821	.0743	.0665	.0588	.0510	.0432	.0354	.0276	.0198	.0120
17.3.....	.0903	.0825	.0747	.0669	.0592	.0514	.0436	.0358	.0280	.0202	.0124
17.4.....	.0907	.0829	.0751	.0673	.0596	.0518	.0440	.0362	.0284	.0206	.0128
17.5.....	.0912	.0834	.0756	.0678	.0600	.0522	.0445	.0367	.0289	.0211	.0133
17.6.....	.0916	.0838	.0760	.0682	.0604	.0526	.0449	.0371	.0293	.0215	.0137
17.7.....	.0920	.0842	.0764	.0686	.0608	.0530	.0453	.0375	.0297	.0219	.0141
17.8.....	.0925	.0847	.0769	.0691	.0613	.0535	.0458	.0380	.0302	.0224	.0146
17.9.....	.0929	.0851	.0773	.0695	.0617	.0539	.0462	.0384	.0306	.0228	.0150
18.0.....	.0933	.0855	.0777	.0699	.0621	.0543	.0466	.0388	.0310	.0232	.0154
18.1.....	.0938	.0860	.0782	.0704	.0626	.0548	.0471	.0392	.0314	.0236	.0158
18.2.....	.0842	.0864	.0786	.0708	.0630	.0552	.0475	.0396	.0318	.0240	.0162
18.3.....	.0946	.0868	.0790	.0712	.0634	.0556	.0479	.0400	.0322	.0244	.0166
18.4.....	.0951	.0873	.0795	.0717	.0639	.0561	.0484	.0405	.0327	.0249	.0171
18.5.....	.0956	.0878	.0800	.0722	.0644	.0566	.0488	.0410	.0332	.0254	.0176
18.6.....	.0960	.0882	.0804	.0726	.0648	.0570	.0492	.0414	.0336	.0258	.0180
18.7.....	.0964	.0886	.0808	.0730	.0652	.0574	.0496	.0418	.0340	.0262	.0184
18.8.....	.0969	.0891	.0813	.0735	.0657	.0579	.0501	.0423	.0345	.0267	.0189
18.9.....	.0974	.0896	.0818	.0740	.0662	.0584	.0506	.0428	.0350	.0272	.0194
19.0.....	.0979	.0901	.0823	.0745	.0667	.0589	.0511	.0433	.0355	.0277	.0199
19.1.....	.0984	.0906	.0828	.0750	.0672	.0594	.0516	.0438	.0360	.0282	.0203
19.2.....	.0988	.0910	.0832	.0754	.0676	.0598	.0520	.0442	.0364	.0286	.0207
19.3.....	.0992	.0914	.0836	.0758	.0680	.0602	.0524	.0446	.0368	.0290	.0211
19.4.....	.0998	.0920	.0842	.0764	.0686	.0608	.0530	.0452	.0374	.0296	.0217
19.5.....	.1002	.0924	.0846	.0768	.0690	.0612	.0534	.0456	.0378	.0300	.0221
19.6.....	.1007	.0929	.0851	.0773	.0695	.0617	.0539	.0461	.0383	.0305	.0226
19.7.....	.1012	.0934	.0856	.0778	.0700	.0622	.0544	.0466	.0388	.0310	.0231
19.8.....	.1017	.0939	.0861	.0783	.0705	.0627	.0549	.0471	.0393	.0315	.0236
19.9.....	.1022	.0944	.0866	.0788	.0710	.0632	.0554	.0476	.0398	.0320	.0241
20.0.....	.1026	.0948	.0870	.0792	.0714	.0636	.0558	.0480	.0402	.0324	.0245

TABLE 9.—*Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F.—Continued.*

Vapor pressure, inches; barometer, 21.42 inches; depression of wet bulb ($T-t'$), °F.
WET BULB, 24° TO 28°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	Proportional parts.	
																		Degrees.	Inches.
24.0	0.1242	0.1164	0.1086	0.1007	0.0929	0.0851	0.0773	0.0694	0.0616	0.0538	0.0460	0.0382	0.0303	0.0225	0.0147			0.1	0.0008
24.1	0.1248	0.1170	0.1092	0.1013	0.0935	0.0857	0.0779	0.0700	0.0622	0.0544	0.0466	0.0387	0.0309	0.0231	0.0153			0.2	0.0016
24.2	0.1254	0.1176	0.1098	0.1019	0.0941	0.0863	0.0785	0.0706	0.0628	0.0550	0.0472	0.0393	0.0315	0.0237	0.0159			0.3	0.0024
24.3	0.1260	0.1182	0.1104	0.1025	0.0947	0.0869	0.0791	0.0712	0.0634	0.0556	0.0478	0.0399	0.0321	0.0243	0.0165			0.4	0.0031
24.4	0.1266	0.1188	0.1110	0.1031	0.0953	0.0875	0.0797	0.0718	0.0640	0.0562	0.0484	0.0405	0.0327	0.0249	0.0171			0.5	0.0039
24.5	0.1272	0.1194	0.1116	0.1037	0.0959	0.0881	0.0803	0.0724	0.0645	0.0567	0.0489	0.0411	0.0333	0.0255	0.0177			0.6	0.0047
24.6	0.1278	0.1200	0.1121	0.1043	0.0965	0.0887	0.0808	0.0729	0.0650	0.0571	0.0493	0.0415	0.0337	0.0259	0.0181			0.7	0.0055
24.7	0.1284	0.1206	0.1127	0.1049	0.0971	0.0893	0.0814	0.0736	0.0658	0.0579	0.0501	0.0423	0.0345	0.0267	0.0189			0.8	0.0063
24.8	0.1290	0.1212	0.1133	0.1055	0.0977	0.0899	0.0820	0.0742	0.0664	0.0586	0.0507	0.0429	0.0351	0.0273	0.0195			0.9	0.0071
24.9	0.1296	0.1218	0.1139	0.1061	0.0983	0.0905	0.0824	0.0748	0.0672	0.0595	0.0513	0.0435	0.0357	0.0279	0.0201				
25.0	0.1302	0.1224	0.1145	0.1067	0.0989	0.0911	0.0832	0.0754	0.0676	0.0598	0.0519	0.0441	0.0363	0.0285	0.0206	0.0128	0.0050		
25.1	0.1308	0.1230	0.1151	0.1073	0.0995	0.0917	0.0838	0.0760	0.0682	0.0604	0.0525	0.0447	0.0369	0.0291	0.0212	0.0134	0.0056		
25.2	0.1314	0.1236	0.1157	0.1079	0.1001	0.0923	0.0844	0.0766	0.0688	0.0610	0.0531	0.0453	0.0375	0.0297	0.0218	0.0140	0.0062		
25.3	0.1320	0.1242	0.1163	0.1085	0.1007	0.0929	0.0850	0.0772	0.0694	0.0616	0.0537	0.0459	0.0381	0.0303	0.0224	0.0146	0.0068		
25.4	0.1327	0.1249	0.1170	0.1092	0.1014	0.0936	0.0857	0.0779	0.0701	0.0623	0.0544	0.0466	0.0388	0.0310	0.0231	0.0153	0.0074		
25.5	0.1333	0.1255	0.1176	0.1098	0.1020	0.0942	0.0863	0.0785	0.0707	0.0629	0.0550	0.0472	0.0394	0.0316	0.0237	0.0159	0.0081		
25.6	0.1339	0.1261	0.1182	0.1104	0.1026	0.0948	0.0869	0.0791	0.0713	0.0635	0.0556	0.0478	0.0400	0.0322	0.0243	0.0165	0.0087		
25.7	0.1346	0.1268	0.1189	0.1111	0.1033	0.0955	0.0876	0.0798	0.0720	0.0642	0.0563	0.0485	0.0407	0.0329	0.0250	0.0172	0.0094		
25.8	0.1352	0.1274	0.1195	0.1117	0.1039	0.0961	0.0882	0.0804	0.0726	0.0648	0.0569	0.0491	0.0413	0.0335	0.0256	0.0178	0.0100		
25.9	0.1358	0.1280	0.1201	0.1123	0.1045	0.0967	0.0888	0.0810	0.0732	0.0654	0.0575	0.0498	0.0419	0.0341	0.0263	0.0184	0.0106		
26.0	0.1365	0.1287	0.1208	0.1130	0.1052	0.0973	0.0895	0.0817	0.0739	0.0660	0.0582	0.0504	0.0425	0.0347	0.0269	0.0190	0.0112		
26.1	0.1371	0.1293	0.1214	0.1136	0.1058	0.0979	0.0901	0.0823	0.0745	0.0666	0.0588	0.0510	0.0431	0.0353	0.0275	0.0196	0.0118		
26.2	0.1377	0.1299	0.1220	0.1142	0.1064	0.0985	0.0907	0.0829	0.0751	0.0672	0.0594	0.0516	0.0437	0.0359	0.0281	0.0202	0.0124		
26.3	0.1384	0.1306	0.1227	0.1149	0.1071	0.0992	0.0914	0.0836	0.0758	0.0679	0.0601	0.0523	0.0444	0.0366	0.0288	0.0209	0.0131		
26.4	0.1390	0.1312	0.1233	0.1155	0.1077	0.0998	0.0920	0.0842	0.0764	0.0685	0.0607	0.0529	0.0450	0.0372	0.0294	0.0215	0.0137		
26.5	0.1396	0.1318	0.1239	0.1161	0.1083	0.1004	0.0926	0.0848	0.0770	0.0691	0.0613	0.0535	0.0456	0.0378	0.0300	0.0221	0.0143		
26.6	0.1403	0.1325	0.1246	0.1168	0.1090	0.1011	0.0933	0.0855	0.0777	0.0698	0.0620	0.0542	0.0463	0.0385	0.0307	0.0228	0.0150		
26.7	0.1410	0.1332	0.1253	0.1175	0.1097	0.1018	0.0940	0.0862	0.0784	0.0705	0.0627	0.0549	0.0470	0.0392	0.0314	0.0235	0.0157		
26.8	0.1416	0.1338	0.1259	0.1181	0.1103	0.1024	0.0946	0.0868	0.0790	0.0711	0.0633	0.0555	0.0476	0.0398	0.0320	0.0241	0.0163		
26.9	0.1423	0.1345	0.1266	0.1188	0.1110	0.1031	0.0953	0.0875	0.0797	0.0718	0.0640	0.0562	0.0483	0.0405	0.0327	0.0248	0.0170		
27.0	0.1430	0.1352	0.1273	0.1195	0.1117	0.1038	0.0960	0.0881	0.0803	0.0725	0.0646	0.0568	0.0490	0.0411	0.0333	0.0255	0.0176		
27.1	0.1436	0.1358	0.1279	0.1201	0.1123	0.1044	0.0966	0.0887	0.0809	0.0731	0.0652	0.0574	0.0496	0.0417	0.0339	0.0262	0.0182		
27.2	0.1443	0.1365	0.1286	0.1208	0.1130	0.1051	0.0973	0.0894	0.0816	0.0738	0.0659	0.0581	0.0503	0.0424	0.0346	0.0269	0.0189		
27.3	0.1450	0.1372	0.1293	0.1215	0.1137	0.1058	0.0980	0.0901	0.0823	0.0745	0.0666	0.0588	0.0510	0.0431	0.0353	0.0276	0.0196		
27.4	0.1456	0.1378	0.1299	0.1221	0.1143	0.1064	0.0986	0.0907	0.0829	0.0751	0.0672	0.0594	0.0516	0.0437	0.0359	0.0282	0.0202		
27.5	0.1463	0.1385	0.1306	0.1228	0.1150	0.1071	0.0993	0.0914	0.0836	0.0758	0.0679	0.0601	0.0523	0.0444	0.0366	0.0289	0.0209		
27.6	0.1470	0.1392	0.1313	0.1235	0.1157	0.1078	0.1000	0.0921	0.0843	0.0765	0.0686	0.0608	0.0530	0.0451	0.0373	0.0296	0.0216		
27.7	0.1476	0.1398	0.1319	0.1241	0.1163	0.1084	0.1006	0.0927	0.0849	0.0771	0.0692	0.0614	0.0536	0.0457	0.0379	0.0302	0.0222		
27.8	0.1483	0.1405	0.1326	0.1248	0.1170	0.1091	0.1013	0.0934	0.0856	0.0778	0.0699	0.0621	0.0543	0.0464	0.0386	0.0309	0.0229		
27.9	0.1490	0.1412	0.1333	0.1255	0.1177	0.1098	0.1020	0.0941	0.0863	0.0785	0.0706	0.0628	0.0549	0.0471	0.0393	0.0316	0.0236		
28.0	0.1497	0.1419	0.1340	0.1262	0.1183	0.1105	0.1027	0.0948	0.0870	0.0791	0.0713	0.0634	0.0556	0.0478	0.0399	0.0321	0.0241		

TABLE D Vapor pressure, inches; depression of wet bulb ($T_w - t'$), °F—Continued.

WET BULB 28° TO 32°.

[illegible]

TABLE 9.—Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F—Continued.
WET BULB 32° TO 36°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0		
32.1	0.181	0.173	0.165	0.157	0.149	0.141	0.134	0.126	0.118	0.110	0.102	0.094	0.085	0.079	0.071	0.063	0.055	0.047	0.039	0.031	0.024	0.016	0.008	---	---		
32.2	0.181	0.173	0.165	0.157	0.149	0.141	0.134	0.126	0.118	0.110	0.102	0.094	0.085	0.079	0.071	0.063	0.055	0.047	0.039	0.031	0.024	0.016	0.008	---	---		
32.3	0.182	0.174	0.166	0.158	0.150	0.142	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.080	0.072	0.064	0.056	0.048	0.040	0.032	0.025	0.018	0.010	---	---		
32.4	0.183	0.175	0.167	0.159	0.151	0.143	0.136	0.128	0.120	0.112	0.104	0.096	0.088	0.081	0.073	0.065	0.058	0.050	0.042	0.034	0.027	0.019	0.011	---	---		
32.5	0.184	0.176	0.168	0.160	0.152	0.144	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.082	0.074	0.066	0.058	0.050	0.042	0.034	0.027	0.019	0.011	---	---		
32.6	0.184	0.176	0.168	0.160	0.152	0.144	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.082	0.074	0.066	0.058	0.050	0.042	0.034	0.027	0.019	0.011	---	---		
32.7	0.185	0.177	0.169	0.161	0.153	0.145	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.083	0.075	0.067	0.059	0.051	0.043	0.036	0.029	0.021	0.013	---	---		
32.8	0.186	0.178	0.170	0.162	0.154	0.146	0.139	0.131	0.123	0.115	0.107	0.099	0.091	0.084	0.076	0.068	0.060	0.052	0.044	0.037	0.030	0.021	0.013	---	---		
32.9	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107	0.099	0.091	0.084	0.076	0.068	0.060	0.052	0.044	0.037	0.030	0.021	0.013	---	---		
33.0	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.132	0.124	0.116	0.108	0.100	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.038	0.030	0.022	0.014	---	---		
33.1	0.188	0.180	0.172	0.164	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.094	0.085	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	0.015	---	---		
33.2	0.189	0.181	0.173	0.165	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.032	0.024	0.016	---	---		
33.3	0.190	0.182	0.174	0.166	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.041	0.033	0.025	0.017	---	---		
33.4	0.191	0.183	0.175	0.167	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.042	0.034	0.026	0.018	---	---		
33.5	0.192	0.184	0.176	0.168	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.043	0.035	0.027	0.019	---	---		
33.6	0.192	0.184	0.176	0.168	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.098	0.090	0.083	0.075	0.067	0.059	0.051	0.044	0.036	0.028	0.020	---	---		
33.7	0.193	0.185	0.177	0.169	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.044	0.036	0.028	0.020	---	---		
33.8	0.193	0.185	0.177	0.169	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.044	0.036	0.028	0.020	---	---		
33.9	0.194	0.186	0.178	0.170	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107	0.100	0.092	0.084	0.076	0.068	0.060	0.052	0.045	0.037	0.029	0.021	---	---		
34.0	0.195	0.187	0.179	0.171	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.100	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.038	0.030	0.022	---	---		
34.1	0.196	0.188	0.180	0.172	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	---	---		
34.2	0.196	0.188	0.180	0.172	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	---	---		
34.3	0.197	0.189	0.181	0.173	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.032	0.024	---	---		
34.4	0.198	0.190	0.182	0.174	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.095	0.088	0.080	0.072	0.064	0.056	0.048	0.041	0.033	0.025	---	---		
34.5	0.199	0.191	0.183	0.175	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.042	0.034	0.026	---	---		
34.6	0.200	0.192	0.184	0.176	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.043	0.035	0.027	---	---		
34.7	0.200	0.192	0.184	0.176	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.098	0.090	0.082	0.074	0.066	0.058	0.051	0.044	0.036	0.028	---	---		
34.8	0.201	0.193	0.185	0.177	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.099	0.091	0.083	0.075	0.068	0.060	0.053	0.045	0.038	0.030	---	---		
34.9	0.202	0.194	0.186	0.178	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107	0.100	0.092	0.084	0.076	0.068	0.060	0.053	0.045	0.038	0.030	---	---		
35.0	0.203	0.195	0.187	0.179	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.038	0.030	0.022	---	---	
35.1	0.204	0.196	0.188	0.180	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	---	---	
35.2	0.204	0.196	0.188	0.180	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	---	---	
35.3	0.205	0.197	0.189	0.181	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.032	0.024	---	---	
35.4	0.206	0.198	0.190	0.182	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.041	0.033	0.025	---	---	
35.5	0.207	0.199	0.191	0.183	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.042	0.034	0.026	---	---	
35.6	0.208	0.200	0.192	0.184	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.043	0.035	0.027	---	---	
35.7	0.208	0.200	0.192	0.184	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.043	0.035	0.027	---	---	
35.8	0.209	0.201	0.193	0.185	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.044	0.036	0.028	---	---	
35.9	0.210	0.202	0.194	0.186	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052	0.044	0.036	0.028	---	---	
36.0	0.211	0.203	0.195	0.187	0.179	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.109	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	---	---
36.1	0.211	0.203	0.195	0.187	0.179	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.109	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	---	---
36.2	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.109	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	---	---
36.3	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.110	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.032	0.024	---	---
36.4	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.111	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.041	0.033	0.025	---	---
36.5	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.112	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.042	0.034	0.026	---	---
36.6	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.113	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.043	0.035	0.027	---</	

TABLE 9. Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T_w - t'$), °F.—Continued.

WET BULB 36° TO 40°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
36.0	0.211	0.203	0.195	0.187	0.179	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.038	0.029	0.022
36.1	0.212	0.204	0.196	0.188	0.180	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.030	0.023
36.2	0.213	0.205	0.197	0.189	0.181	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.031	0.024
36.3	0.213	0.205	0.197	0.189	0.181	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.031	0.024
36.4	0.214	0.206	0.198	0.190	0.182	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.041	0.032	0.025
36.5	0.215	0.207	0.199	0.191	0.183	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.042	0.033	0.026
36.6	0.216	0.208	0.200	0.192	0.184	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.043	0.034	0.027
36.7	0.217	0.209	0.201	0.193	0.185	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.052	0.044	0.036	0.029
36.8	0.217	0.209	0.201	0.193	0.185	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.052	0.044	0.036	0.029
36.9	0.218	0.210	0.202	0.194	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052	0.045	0.037	0.030
37.0	0.219	0.211	0.203	0.195	0.187	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052	0.045	0.038	0.030
37.1	0.220	0.212	0.204	0.196	0.188	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.046	0.039	0.031
37.2	0.221	0.213	0.205	0.197	0.189	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.047	0.040	0.032
37.3	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.047	0.040	0.032
37.4	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.032
37.5	0.224	0.216	0.208	0.200	0.192	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.050	0.042	0.034
37.6	0.225	0.217	0.209	0.201	0.193	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.051	0.043	0.035
37.7	0.225	0.217	0.209	0.201	0.193	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.051	0.043	0.035
37.8	0.226	0.218	0.210	0.202	0.194	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.052	0.044	0.036
37.9	0.227	0.219	0.211	0.203	0.195	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.053	0.045	0.037
38.0	0.228	0.220	0.212	0.204	0.196	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.046	0.038
38.1	0.229	0.221	0.213	0.205	0.197	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.047	0.039
38.2	0.230	0.222	0.214	0.206	0.198	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.048	0.040
38.3	0.231	0.223	0.215	0.207	0.199	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.049	0.041
38.4	0.232	0.224	0.216	0.208	0.200	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.050	0.042
38.5	0.233	0.225	0.217	0.209	0.201	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.051	0.043
38.6	0.233	0.225	0.217	0.209	0.201	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.098	0.091	0.083	0.075	0.067	0.059	0.052	0.044
38.7	0.234	0.226	0.218	0.210	0.202	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.052	0.044
38.8	0.235	0.227	0.219	0.211	0.203	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.053	0.045
38.9	0.236	0.228	0.220	0.212	0.204	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.054	0.046
39.0	0.237	0.229	0.221	0.213	0.205	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046
39.1	0.238	0.230	0.222	0.214	0.206	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047
39.2	0.239	0.231	0.223	0.215	0.207	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048
39.3	0.240	0.232	0.224	0.216	0.208	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049
39.4	0.241	0.233	0.225	0.217	0.209	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050
39.5	0.242	0.234	0.226	0.218	0.210	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051
39.6	0.243	0.235	0.227	0.219	0.211	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052
39.7	0.244	0.236	0.228	0.220	0.212	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053
39.8	0.245	0.237	0.229	0.221	0.213	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054
39.9	0.246	0.238	0.230	0.222	0.214	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055
40.0	0.247	0.239	0.231	0.223	0.215	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056

TABLE 9.—*Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F—Continued.*

WET BULB, 40° TO 44°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0
40.1.....	0.247	0.239	0.231	0.223	0.215	0.207	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.121	0.113
40.2.....	0.248	0.240	0.232	0.224	0.216	0.208	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.122	0.114
40.3.....	0.249	0.241	0.233	0.225	0.217	0.209	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.123	0.115
40.4.....	0.250	0.242	0.234	0.226	0.218	0.210	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.124	0.116
40.5.....	0.251	0.243	0.235	0.227	0.219	0.211	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.125	0.117
40.6.....	0.252	0.244	0.236	0.228	0.220	0.212	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.126	0.118
40.7.....	0.253	0.245	0.237	0.229	0.221	0.213	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.127	0.119
40.8.....	0.254	0.246	0.238	0.230	0.222	0.214	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.128	0.120
40.9.....	0.255	0.247	0.239	0.231	0.223	0.215	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.129	0.121
41.0.....	0.256	0.248	0.240	0.232	0.224	0.216	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.130	0.122
41.1.....	0.257	0.249	0.241	0.233	0.225	0.217	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.131	0.123
41.2.....	0.258	0.250	0.242	0.234	0.226	0.218	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.132	0.124
41.3.....	0.259	0.251	0.243	0.235	0.227	0.219	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.133	0.125
41.4.....	0.260	0.252	0.244	0.236	0.228	0.220	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.134	0.126
41.5.....	0.261	0.253	0.245	0.237	0.229	0.221	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.135	0.127
41.6.....	0.262	0.254	0.246	0.238	0.230	0.222	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.136	0.128
41.7.....	0.263	0.255	0.247	0.239	0.231	0.223	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.137	0.129
41.8.....	0.264	0.256	0.248	0.240	0.232	0.224	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.130
41.9.....	0.265	0.257	0.249	0.241	0.233	0.225	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.131
42.0.....	0.266	0.258	0.250	0.242	0.234	0.226	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.132
42.1.....	0.267	0.259	0.251	0.243	0.235	0.227	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.133
42.2.....	0.268	0.260	0.252	0.244	0.236	0.228	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.134
42.3.....	0.269	0.261	0.253	0.245	0.237	0.229	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.135
42.4.....	0.270	0.262	0.254	0.246	0.238	0.230	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.136
42.5.....	0.271	0.263	0.255	0.247	0.239	0.231	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.137
42.6.....	0.272	0.264	0.256	0.248	0.240	0.232	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.138
42.7.....	0.273	0.265	0.257	0.249	0.241	0.233	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.139
42.8.....	0.274	0.266	0.258	0.250	0.242	0.234	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.140
42.9.....	0.275	0.267	0.259	0.251	0.243	0.235	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.141
43.0.....	0.276	0.268	0.260	0.252	0.244	0.236	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.142
43.1.....	0.277	0.269	0.261	0.253	0.245	0.237	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.143
43.2.....	0.278	0.270	0.262	0.254	0.246	0.238	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.144
43.3.....	0.279	0.271	0.263	0.255	0.247	0.239	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.145
43.4.....	0.280	0.272	0.264	0.256	0.248	0.240	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.146
43.5.....	0.281	0.273	0.265	0.257	0.249	0.241	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.147
43.6.....	0.282	0.274	0.266	0.258	0.250	0.242	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.148
43.7.....	0.283	0.275	0.267	0.259	0.251	0.243	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.149
43.8.....	0.284	0.276	0.268	0.260	0.252	0.244	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.150
43.9.....	0.285	0.277	0.269	0.261	0.253	0.245	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.151
44.0.....	0.286	0.278	0.270	0.262	0.254	0.246	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.152
44.1.....	0.287	0.279	0.271	0.263	0.255	0.247	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.153

TABLE 9.—Vapor pressure, inches; depression of wet bulb ($T'-t'$), °F.—Continued.

WET BULB, 40° TO 44°.

[illegible]

TABLE 9.—*Vapor pressure, inches; barometer 24.2 inches; depression of wet bulb ($T_w - T$), °F—Continued.*

WET BULB 44° TO 48°.																										
Wet bulb.		DEPRESSION OF WET ($T - T'$) FAHR.																								
		0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0			15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
44.1	0.288	0.280	0.272	0.264	0.256	0.248	0.240	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.138	0.130	0.122	0.114	0.106	0.107	
44.2	0.289	0.281	0.273	0.265	0.257	0.249	0.241	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.139	0.131	0.123	0.115	0.107	0.109	
44.3	0.291	0.283	0.275	0.267	0.259	0.251	0.243	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.141	0.133	0.125	0.117	0.109	0.110	
44.4	0.292	0.284	0.276	0.268	0.260	0.252	0.244	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.142	0.134	0.126	0.118	0.111	0.112	
44.5	0.293	0.285	0.277	0.269	0.261	0.253	0.245	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.143	0.136	0.128	0.120	0.112	0.113	
44.6	0.294	0.286	0.278	0.270	0.262	0.254	0.246	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.144	0.137	0.129	0.121	0.114	0.114	
44.7	0.295	0.287	0.279	0.271	0.263	0.255	0.247	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.145	0.138	0.130	0.122	0.115	0.115	
44.8	0.296	0.288	0.280	0.272	0.264	0.256	0.248	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.146	0.139	0.131	0.123	0.116	0.116	
44.9	0.297	0.289	0.281	0.273	0.265	0.257	0.249	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.147	0.139	0.131	0.123	0.116	0.116	
45.0	0.298	0.290	0.282	0.274	0.266	0.258	0.250	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.148	0.140	0.132	0.124	0.117	0.118	
45.1	0.300	0.292	0.284	0.276	0.268	0.260	0.252	0.244	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.118	0.119	
45.2	0.301	0.293	0.285	0.277	0.269	0.261	0.253	0.245	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.119	0.120	
45.3	0.302	0.294	0.286	0.278	0.270	0.262	0.254	0.246	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.120	0.121	
45.4	0.303	0.295	0.287	0.279	0.271	0.263	0.255	0.247	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.121	0.122	
45.5	0.304	0.296	0.288	0.280	0.272	0.264	0.256	0.248	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.122	0.123	
45.6	0.305	0.297	0.289	0.281	0.273	0.265	0.257	0.249	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.123	0.124	
45.7	0.306	0.298	0.290	0.282	0.274	0.266	0.258	0.250	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.124	0.125	
45.8	0.308	0.300	0.292	0.284	0.276	0.268	0.260	0.252	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.126	0.127	
45.9	0.309	0.301	0.293	0.285	0.277	0.269	0.261	0.253	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.127	0.128	
46.0	0.310	0.302	0.294	0.286	0.278	0.270	0.262	0.254	0.247	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.128	0.129	
46.1	0.311	0.303	0.295	0.287	0.279	0.271	0.263	0.255	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.129	0.130	
46.2	0.312	0.304	0.296	0.288	0.280	0.272	0.264	0.256	0.249	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.130	0.131	
46.3	0.313	0.305	0.297	0.289	0.281	0.273	0.265	0.257	0.250	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.131	0.133	
46.4	0.315	0.307	0.299	0.291	0.283	0.275	0.267	0.259	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.133	0.134	
46.5	0.316	0.308	0.300	0.292	0.284	0.276	0.268	0.260	0.253	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.134	0.135	
46.6	0.317	0.309	0.301	0.293	0.285	0.277	0.269	0.261	0.254	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.135	
46.7	0.318	0.310	0.302	0.294	0.286	0.278	0.270	0.262	0.255	0.247	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.136	
46.8	0.319	0.311	0.303	0.295	0.287	0.279	0.271	0.263	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.138	
46.9	0.321	0.313	0.305	0.297	0.289	0.281	0.273	0.265	0.258	0.250	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.139	
47.0	0.322	0.314	0.306	0.298	0.290	0.282	0.274	0.266	0.259	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.140	
47.1	0.323	0.315	0.307	0.299	0.291	0.283	0.275	0.267	0.260	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.141	
47.2	0.324	0.316	0.308	0.300	0.292	0.284	0.276	0.268	0.261	0.253	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.142	
47.3	0.325	0.317	0.309	0.301	0.293	0.285	0.277	0.269	0.262	0.254	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.144	
47.4	0.327	0.319	0.311	0.303	0.295	0.287	0.279	0.271	0.263	0.255	0.247	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.145	
47.5	0.328	0.320	0.312	0.304	0.296	0.288	0.280	0.272	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.146	
47.6	0.329	0.321	0.313	0.305	0.297	0.289	0.281	0.273	0.265	0.257	0.249	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.146	
47.7	0.330	0.322	0.314	0.306	0.298	0.290	0.282	0.274	0.266	0.258	0.250	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.147	
47.8	0.331	0.323	0.315	0.307	0.299	0.291	0.283	0.275	0.267	0.259	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.149	
47.9	0.332	0.324	0.316	0.308	0.300	0.292	0.284	0.276	0.268	0.260	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.150	
48.0	0.333	0.325	0.317	0.309	0.301	0.293	0.285	0.277	0.269	0.261	0.253	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.151	
48.1	0.334	0.326	0.318	0.310	0.302	0.294	0.286	0.278	0.270	0.262	0.254	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.151	

TABLE 9.—*Vapor pressure, inches; barometer 21.2 inches; depression of wet bulb ($T-t'$), °F—Continued.*

WET BULB 44.1 TO 50°—Continued.

Wet bulb.	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
44.1.....	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.042	0.035	0.027	0.019	0.011	0.003	.....	.....	.....	.....	.....	.....	.....
44.2.....	0.089	0.081	0.073	0.065	0.057	0.049	0.041	0.033	0.025	0.017	0.009	0.001	.....	.....	.....	.....	.....	.....	.....	.....
44.3.....	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.038	0.030	0.022	0.014	0.006	.....	.....	.....	.....	.....	.....	.....
44.4.....	0.103	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.039	0.031	0.023	0.015	0.007	.....	.....	.....	.....	.....	.....	.....
44.5.....	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.040	0.032	0.024	0.016	0.008	.....	.....	.....	.....	.....	.....	.....
44.6.....	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.040	0.032	0.025	0.017	0.009	.....	.....	.....	.....	.....	.....	.....
44.7.....	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.041	0.033	0.026	0.018	0.010	.....	.....	.....	.....	.....	.....	.....
44.8.....	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.042	0.034	0.027	0.019	0.011	.....	.....	.....	.....	.....	.....	.....
44.9.....	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.043	0.035	0.028	0.020	0.012	.....	.....	.....	.....	.....	.....	.....
45.0.....	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052	0.044	0.036	0.029	0.021	0.013	0.005	.....	.....	.....	.....	.....	.....
45.1.....	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.038	0.030	0.022	0.014	0.007	.....	.....	.....	.....	.....	.....
45.2.....	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.039	0.031	0.023	0.015	0.008	.....	.....	.....	.....	.....	.....
45.3.....	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.040	0.032	0.024	0.016	0.009	.....	.....	.....	.....	.....	.....
45.4.....	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.041	0.033	0.025	0.017	0.010	.....	.....	.....	.....	.....	.....
45.5.....	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.042	0.034	0.026	0.018	0.011	.....	.....	.....	.....	.....	.....
45.6.....	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.043	0.035	0.027	0.019	0.012	.....	.....	.....	.....	.....	.....
45.7.....	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052	0.044	0.036	0.028	0.020	0.013	.....	.....	.....	.....	.....	.....
45.8.....	0.118	0.110	0.102	0.094	0.086	0.078	0.080	0.062	0.054	0.046	0.038	0.029	0.021	0.015	.....	.....	.....	.....	.....	.....
45.9.....	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.039	0.031	0.022	0.016	.....	.....	.....	.....	.....	.....
46.0.....	0.120	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.040	0.032	0.024	0.017	0.009	.....	.....	.....	.....	.....
46.1.....	0.121	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.041	0.033	0.025	0.018	0.010	.....	.....	.....	.....	.....
46.2.....	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.042	0.034	0.026	0.019	0.011	.....	.....	.....	.....	.....
46.3.....	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.043	0.035	0.027	0.020	0.012	.....	.....	.....	.....	.....
46.4.....	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.037	0.029	0.022	0.014	.....	.....	.....	.....	.....
46.5.....	0.126	0.118	0.110	0.102	0.094	0.087	0.079	0.071	0.063	0.055	0.047	0.039	0.031	0.023	0.015	.....	.....	.....	.....	.....
46.6.....	0.127	0.119	0.111	0.103	0.095	0.088	0.080	0.072	0.064	0.056	0.048	0.040	0.032	0.024	0.016	.....	.....	.....	.....	.....
46.7.....	0.128	0.120	0.112	0.104	0.096	0.089	0.081	0.073	0.065	0.057	0.049	0.041	0.033	0.025	0.017	.....	.....	.....	.....	.....
46.8.....	0.129	0.121	0.113	0.105	0.097	0.090	0.082	0.074	0.066	0.058	0.050	0.042	0.034	0.026	0.018	.....	.....	.....	.....	.....
46.9.....	0.131	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.043	0.035	0.027	0.019	0.012	0.005	.....	.....	.....
47.0.....	0.132	0.124	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052	0.044	0.036	0.028	0.020	0.012	0.005	.....	.....	.....
47.1.....	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.037	0.029	0.021	0.013	0.006	.....	.....	.....
47.2.....	0.134	0.126	0.118	0.110	0.102	0.093	0.086	0.078	0.070	0.062	0.054	0.046	0.038	0.030	0.022	0.014	0.007	.....	.....	.....
47.3.....	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.039	0.031	0.023	0.015	0.008	.....	.....	.....
47.4.....	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057	0.049	0.041	0.033	0.025	0.017	0.009	.....	.....	.....
47.5.....	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058	0.050	0.042	0.034	0.026	0.018	0.010	.....	.....	.....
47.6.....	0.138	0.130	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051	0.043	0.035	0.027	0.019	0.011	.....	.....	.....
47.7.....	0.139	0.131	0.124	0.116	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053	0.045	0.036	0.028	0.020	0.012	.....	.....	.....
47.8.....	0.141	0.133	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054	0.046	0.038	0.030	0.022	0.014	.....	.....	.....
47.9.....	0.142	0.134	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063	0.055	0.047	0.039	0.031	0.023	0.015	.....	.....	.....
48.0.....	0.143	0.135	0.128	0.120	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056	0.048	0.040	0.032	0.024	0.016	0.008	.....	.....

TABLE 9.—Vapor pressure, inches; barometer 21.12 inches; depression of wet bulb ($T-t'$), °F—Continued.

WET BULB 44.1 TO 50°—Continued.

Wet bulb.	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
48.1														0.041	0.033	0.025	0.017	0.009		
48.2														.043	.035	.027	.019	.011		
48.3														.044	.036	.028	.020	.012		
48.4														.045	.037	.029	.021	.013		
48.5														.046	.038	.030	.022	.014		
48.6														.048	.040	.032	.024	.016		
48.7														.049	.041	.033	.025	.017		
48.8														.050	.042	.034	.026	.018		
48.9														.052	.044	.036	.028	.020		
49.0														.053	.045	.037	.029	.021	0.013	
49.1														.054	.046	.038	.030	.022	.014	
49.2														.055	.047	.039	.031	.023	.015	
49.3														.057	.049	.041	.033	.025	.017	
49.4														.058	.050	.042	.034	.026	.018	
49.5														.059	.051	.043	.035	.027	.019	
49.6														.061	.053	.045	.037	.029	.021	
49.7														.062	.054	.046	.038	.030	.022	
49.8														.063	.055	.046	.039	.031	.023	
49.9														.065	.057	.048	.041	.033	.025	
50.0														.066	.058	.050	.042	.034	.026	0.018

TABLE 9. Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T_w - T_d$), °F.—Continued.

WET BULB 48.1° TO 52°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
48.1	0.337	0.327	0.319	0.311	0.303	0.295	0.287	0.279	0.271	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192
48.2	0.337	0.329	0.321	0.313	0.305	0.297	0.289	0.281	0.273	0.266	0.258	0.250	0.242	0.234	0.226	0.218	0.210	0.202	0.194
48.3	0.338	0.330	0.322	0.314	0.306	0.298	0.290	0.282	0.274	0.267	0.259	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195
48.4	0.339	0.331	0.323	0.315	0.307	0.299	0.291	0.283	0.275	0.268	0.260	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196
48.5	0.340	0.332	0.324	0.316	0.308	0.300	0.292	0.284	0.276	0.269	0.261	0.253	0.245	0.237	0.229	0.221	0.213	0.205	0.197
48.6	0.342	0.334	0.326	0.318	0.310	0.302	0.294	0.286	0.278	0.271	0.263	0.255	0.247	0.239	0.231	0.223	0.215	0.207	0.199
48.7	0.343	0.335	0.327	0.319	0.311	0.303	0.295	0.287	0.279	0.272	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.200
48.8	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.288	0.280	0.273	0.265	0.257	0.249	0.241	0.233	0.225	0.217	0.209	0.201
48.9	0.345	0.337	0.329	0.321	0.314	0.306	0.298	0.290	0.282	0.275	0.266	0.258	0.250	0.242	0.235	0.226	0.218	0.210	0.202
49.0	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.291	0.283	0.275	0.268	0.260	0.252	0.244	0.236	0.228	0.220	0.212	0.204
49.1	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.292	0.284	0.276	0.269	0.261	0.253	0.245	0.237	0.229	0.221	0.213	0.205
49.2	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293	0.285	0.277	0.270	0.262	0.254	0.246	0.238	0.230	0.222	0.214	0.206
49.3	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.295	0.287	0.279	0.272	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208
49.4	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.288	0.280	0.272	0.265	0.257	0.249	0.241	0.233	0.225	0.217	0.209
49.5	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.297	0.289	0.281	0.273	0.266	0.258	0.250	0.242	0.234	0.226	0.218	0.210
49.6	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.291	0.283	0.275	0.268	0.260	0.252	0.244	0.236	0.228	0.220	0.212
49.7	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.292	0.284	0.276	0.269	0.261	0.253	0.245	0.237	0.229	0.221	0.213
49.8	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293	0.285	0.277	0.270	0.262	0.254	0.246	0.238	0.230	0.222	0.214
49.9	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.294	0.286	0.278	0.271	0.263	0.255	0.247	0.239	0.231	0.223	0.215
50.0	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.288	0.280	0.273	0.265	0.257	0.249	0.241	0.233	0.225	0.217
50.1	0.361	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.297	0.289	0.281	0.274	0.266	0.258	0.250	0.242	0.234	0.226	0.218
50.2	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.290	0.282	0.275	0.267	0.259	0.251	0.243	0.235	0.227	0.219
50.3	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.291	0.283	0.276	0.268	0.260	0.252	0.244	0.236	0.228	0.220
50.4	0.364	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.292	0.284	0.277	0.269	0.261	0.253	0.245	0.237	0.229	0.221
50.5	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293	0.285	0.278	0.270	0.262	0.254	0.246	0.238	0.230	0.222
50.6	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.294	0.286	0.279	0.271	0.263	0.255	0.247	0.239	0.231	0.223
50.7	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.295	0.287	0.280	0.272	0.264	0.256	0.248	0.240	0.232	0.224
50.8	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.288	0.281	0.273	0.265	0.257	0.249	0.241	0.233	0.225
50.9	0.369	0.361	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.297	0.289	0.282	0.274	0.266	0.258	0.250	0.242	0.234	0.226
51.0	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.290	0.283	0.275	0.267	0.259	0.251	0.243	0.235	0.227
51.1	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.291	0.284	0.276	0.268	0.260	0.252	0.244	0.236	0.228
51.2	0.372	0.364	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.292	0.285	0.277	0.269	0.261	0.253	0.245	0.237	0.229
51.3	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293	0.286	0.278	0.270	0.262	0.254	0.246	0.238	0.230
51.4	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.294	0.287	0.279	0.271	0.263	0.255	0.247	0.239	0.231
51.5	0.375	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.295	0.288	0.280	0.272	0.264	0.256	0.248	0.240	0.232
51.6	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.289	0.281	0.273	0.265	0.257	0.249	0.241	0.233
51.7	0.377	0.369	0.361	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.297	0.290	0.282	0.274	0.266	0.258	0.250	0.242	0.234
51.8	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.291	0.283	0.275	0.267	0.259	0.251	0.243	0.235
51.9	0.379	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.292	0.284	0.276	0.268	0.260	0.252	0.244	0.236
52.0	0.380	0.372	0.364	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.292	0.284	0.276	0.268	0.260	0.252	0.244	0.236
52.1	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293	0.285	0.277	0.269	0.261	0.253	0.245	0.237
52.2	0.382	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.294	0.286	0.278	0.270	0.262	0.254	0.246	0.238
52.3	0.383	0.375	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.295	0.287	0.279	0.271	0.263	0.255	0.247	0.239
52.4	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.288	0.280	0.272	0.264	0.256	0.248	0.240
52.5	0.385	0.377	0.369	0.361	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.297	0.289	0.281	0.273	0.265	0.257	0.249	0.241
52.6	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.290	0.282	0.274	0.266	0.258	0.250	0.242
52.7	0.387	0.379	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.291	0.283	0.275	0.267	0.259	0.251	0.243
52.8	0.388	0.380	0.372	0.364	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.299	0.291	0.283	0.275	0.267	0.259	0.251	0.243
52.9	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.299	0.291	0.283	0.275	0.267	0.259	0.251	0.243
53.0	0.390	0.382	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.300	0.291	0.283	0.275	0.267	0.259	0.251	0.243
53.1	0.391	0.383	0.375	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.301	0.292	0.284	0.276	0.268	0.260	0.252	0.244

TABLE 9.—*Vapor pressure, inches; barometer 21.12 inches; depression of wet bulb ($T-t'$), °F—Continued.*

WET BULB 48.1° TO 52°—(Continued).

Wet bulb.	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0
48.1.....	0.181	0.176	0.168	0.160	0.152	0.144	0.136	0.129	0.121	0.113	0.105	0.197	0.089	0.081	0.073	0.065	0.057	0.049
48.2.....	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.131	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059	0.051
48.3.....	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.132	0.124	0.116	0.108	0.100	0.092	0.084	0.076	0.068	0.060	0.052
48.4.....	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061	0.053
48.5.....	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062	0.054
48.6.....	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.136	0.128	0.120	0.112	0.104	0.096	0.088	0.080	0.072	0.064	0.056
48.7.....	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.081	0.073	0.065	0.057
48.8.....	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066	0.058
48.9.....	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.139	0.131	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067	0.059
49.0.....	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.141	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069	0.061
49.1.....	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070	0.062
49.2.....	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.143	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071	0.063
49.3.....	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.145	0.137	0.129	0.121	0.113	0.105	0.097	0.089	0.081	0.073	0.065
49.4.....	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.146	0.138	0.130	0.122	0.114	0.106	0.098	0.090	0.082	0.074	0.066
49.5.....	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.147	0.139	0.131	0.123	0.115	0.107	0.099	0.091	0.083	0.075	0.067
49.6.....	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.149	0.141	0.133	0.125	0.117	0.109	0.101	0.093	0.085	0.077	0.069
49.7.....	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.086	0.078	0.070
49.8.....	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.095	0.087	0.079	0.071
49.9.....	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.096	0.088	0.080	0.072
50.0.....	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.114	0.106	0.098	0.090	0.082	0.074
50.1.....	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.115	0.107	0.099	0.091	0.083	0.075
50.2.....	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.116	0.108	0.100	0.092	0.084	0.076
50.3.....	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.118	0.110	0.102	0.094	0.086	0.078
50.4.....	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.119	0.111	0.103	0.095	0.087	0.079
50.5.....	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.121	0.113	0.105	0.097	0.089	0.081
50.6.....	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.114	0.106	0.098	0.090	0.082
50.7.....	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.115	0.107	0.099	0.091	0.083
50.8.....	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.117	0.109	0.101	0.093	0.085
50.9.....	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.132	0.125	0.118	0.110	0.102	0.094	0.086
51.0.....	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102	0.094	0.087
51.1.....	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.097	0.089
51.2.....	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.098	0.090
51.3.....	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106	0.099	0.091
51.4.....	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.101	0.093
51.5.....	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109	0.102	0.094
51.6.....	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103	0.096
51.7.....	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112	0.104	0.097
51.8.....	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105	0.098
51.9.....	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107	0.099
52.0.....	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116	0.108	0.100

TABLE 9.—Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T - t'$), °F. Continued.

WET BULB 52.1° TO 56°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
52.1.....	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.294	0.286	0.278	0.270	0.262	0.254	0.246
52.2.....	0.390	0.382	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.295	0.287	0.279	0.271	0.263	0.255	0.247
52.3.....	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.297	0.289	0.281	0.273	0.265	0.257	0.249
52.4.....	0.393	0.385	0.377	0.369	0.361	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.298	0.290	0.282	0.274	0.266	0.258	0.250
52.5.....	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.299	0.291	0.283	0.275	0.267	0.259	0.251
52.6.....	0.396	0.388	0.380	0.372	0.364	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.293	0.285	0.277	0.269	0.261	0.253
52.7.....	0.397	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.294	0.286	0.278	0.270	0.262	0.254
52.8.....	0.399	0.391	0.383	0.375	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.296	0.288	0.280	0.272	0.264	0.256
52.9.....	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.297	0.289	0.281	0.273	0.265	0.257
53.0.....	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.291	0.283	0.275	0.267	0.259
53.1.....	0.403	0.395	0.387	0.379	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.292	0.284	0.276	0.268	0.260
53.2.....	0.405	0.397	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.294	0.286	0.278	0.270	0.262
53.3.....	0.406	0.398	0.390	0.382	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.295	0.287	0.279	0.271	0.263
53.4.....	0.408	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.297	0.289	0.281	0.273	0.265
53.5.....	0.409	0.401	0.393	0.385	0.377	0.369	0.361	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.298	0.290	0.282	0.274	0.266
53.6.....	0.411	0.403	0.395	0.387	0.379	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.292	0.284	0.276	0.268
53.7.....	0.412	0.404	0.396	0.388	0.380	0.372	0.364	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.293	0.285	0.277	0.269
53.8.....	0.414	0.406	0.398	0.390	0.382	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.295	0.287	0.279	0.271
53.9.....	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.296	0.288	0.280	0.272
54.0.....	0.417	0.409	0.401	0.393	0.385	0.377	0.369	0.361	0.353	0.345	0.337	0.329	0.321	0.313	0.305	0.297	0.289	0.281	0.273
54.1.....	0.418	0.410	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.290	0.282	0.274
54.2.....	0.420	0.412	0.404	0.396	0.388	0.380	0.372	0.364	0.356	0.348	0.340	0.332	0.324	0.316	0.308	0.300	0.292	0.284	0.276
54.3.....	0.421	0.413	0.405	0.397	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293	0.285	0.277
54.4.....	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.295	0.287	0.279
54.5.....	0.424	0.416	0.408	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.288	0.280
54.6.....	0.426	0.418	0.410	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.290	0.282
54.7.....	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.291	0.283
54.8.....	0.429	0.421	0.413	0.405	0.397	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293	0.285
54.9.....	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.359	0.351	0.343	0.335	0.327	0.319	0.311	0.303	0.295	0.287
55.0.....	0.432	0.424	0.416	0.408	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296	0.288
55.1.....	0.434	0.426	0.418	0.410	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.290
55.2.....	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299	0.291
55.3.....	0.437	0.429	0.421	0.413	0.405	0.397	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301	0.293
55.4.....	0.438	0.430	0.422	0.414	0.406	0.398	0.390	0.382	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302	0.294
55.5.....	0.440	0.432	0.424	0.416	0.408	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304	0.296
55.6.....	0.442	0.434	0.426	0.418	0.410	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298
55.7.....	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371	0.363	0.355	0.347	0.339	0.331	0.323	0.315	0.307	0.299
55.8.....	0.445	0.437	0.429	0.421	0.413	0.405	0.397	0.389	0.381	0.373	0.365	0.357	0.349	0.341	0.333	0.325	0.317	0.309	0.301
55.9.....	0.446	0.438	0.430	0.422	0.414	0.406	0.398	0.390	0.382	0.374	0.366	0.358	0.350	0.342	0.334	0.326	0.318	0.310	0.302
56.0.....	0.448	0.440	0.432	0.424	0.416	0.408	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336	0.328	0.320	0.312	0.304

TABLE 9.—*Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), °F—Continued.*
 WET BULB 52.1° TO 56°—Continued.

Wet bulb.	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0
52.1.....	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110	0.102
52.2.....	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119	0.111	0.103
52.3.....	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113	0.105
52.4.....	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122	0.114	0.106
52.5.....	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115	0.107
52.6.....	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125	0.117	0.109
52.7.....	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118	0.110
52.8.....	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128	0.120	0.112
52.9.....	0.249	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121	0.113
53.0.....	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131	0.123	0.115
53.1.....	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124	0.116
53.2.....	0.254	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134	0.126	0.118
53.3.....	0.255	0.247	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127	0.119
53.4.....	0.257	0.249	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137	0.129	0.121
53.5.....	0.258	0.250	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130	0.122
53.6.....	0.260	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140	0.132	0.124
53.7.....	0.261	0.253	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133	0.125
53.8.....	0.263	0.255	0.247	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151	0.143	0.135	0.127
53.9.....	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136	0.128
54.0.....	0.266	0.258	0.250	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154	0.146	0.138	0.130
54.1.....	0.267	0.259	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139	0.131
54.2.....	0.269	0.261	0.253	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157	0.149	0.141	0.133
54.3.....	0.270	0.262	0.254	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142	0.134
54.4.....	0.272	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144	0.136
54.5.....	0.273	0.265	0.257	0.249	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145	0.137
54.6.....	0.275	0.267	0.259	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147	0.139
54.7.....	0.276	0.268	0.260	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148	0.140
54.8.....	0.278	0.270	0.262	0.254	0.247	0.239	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150	0.142
54.9.....	0.279	0.271	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.200	0.192	0.184	0.176	0.168	0.160	0.152	0.144
55.0.....	0.280	0.272	0.265	0.257	0.249	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153	0.145
55.1.....	0.282	0.274	0.267	0.259	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155	0.147
55.2.....	0.283	0.275	0.268	0.260	0.252	0.244	0.236	0.228	0.220	0.212	0.204	0.196	0.188	0.180	0.172	0.164	0.156	0.148
55.3.....	0.285	0.277	0.270	0.262	0.254	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158	0.150
55.4.....	0.286	0.278	0.271	0.263	0.255	0.247	0.239	0.231	0.223	0.215	0.207	0.199	0.191	0.183	0.175	0.167	0.159	0.151
55.5.....	0.288	0.280	0.273	0.265	0.257	0.249	0.241	0.233	0.225	0.217	0.209	0.201	0.193	0.185	0.177	0.169	0.161	0.153
55.6.....	0.290	0.282	0.274	0.266	0.258	0.250	0.242	0.234	0.226	0.218	0.210	0.202	0.194	0.186	0.178	0.170	0.162	0.154
55.7.....	0.291	0.283	0.275	0.267	0.259	0.251	0.243	0.235	0.227	0.219	0.211	0.203	0.195	0.187	0.179	0.171	0.163	0.155
55.8.....	0.293	0.285	0.277	0.269	0.261	0.253	0.245	0.237	0.229	0.221	0.213	0.205	0.197	0.189	0.181	0.173	0.165	0.157
55.9.....	0.294	0.286	0.278	0.270	0.262	0.254	0.246	0.238	0.230	0.222	0.214	0.206	0.198	0.190	0.182	0.174	0.166	0.158
56.0.....	0.296	0.288	0.280	0.272	0.264	0.256	0.248	0.240	0.232	0.224	0.216	0.208	0.199	0.191	0.183	0.175	0.167	0.159

TABLE 9.—Vapor pressure, inches; barometer 24.2 inches; depression of wet bulb ($T_w - t'$), ° F.—Continued.

WET BULB 56.4° TO 60°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
56.1	0.430	0.442	0.454	0.426	0.418	0.410	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338	0.330	0.322	0.314	0.306	0.298	0.290	0.282	0.274	0.266	0.258
56.2	451	445	437	427	419	411	403	395	387	379	371	363	355	347	339	331	323	315	307	299	291	283	275	267	259
56.3	453	447	439	429	421	413	405	397	389	381	373	365	357	349	341	333	325	317	309	301	293	285	277	269	261
56.4	455	449	441	432	424	416	408	400	392	384	376	368	360	352	344	336	328	320	312	304	296	288	280	272	264
56.5	458	450	442	434	426	418	410	402	394	386	378	370	362	354	346	338	330	322	314	306	298	290	282	274	266
56.6	460	452	444	436	428	420	412	404	396	388	380	372	364	356	348	340	332	324	316	308	300	292	284	276	268
56.7	461	453	445	437	429	421	413	405	397	389	381	373	365	357	349	341	333	325	317	309	301	293	285	277	269
56.8	463	455	447	439	431	423	415	407	399	391	383	375	367	359	351	343	335	327	319	311	303	295	287	279	271
56.9	465	457	449	441	433	425	417	409	401	393	385	377	369	361	353	345	337	329	321	313	305	297	289	281	273
57.0	466	458	450	442	434	426	418	410	402	394	386	378	370	362	354	346	338	330	322	314	306	298	290	282	274
57.1	468	460	452	444	436	428	420	412	404	396	388	380	372	364	356	348	340	332	324	316	308	300	292	284	276
57.2	470	462	454	446	438	430	422	414	406	398	390	382	374	366	358	350	342	334	326	318	310	302	294	286	278
57.3	471	463	455	447	439	431	423	415	407	399	391	383	375	367	359	351	343	335	327	319	311	303	295	287	279
57.4	473	465	457	449	441	433	425	417	409	401	393	385	377	369	361	353	345	337	329	321	313	305	297	289	281
57.5	475	467	459	451	443	435	427	419	411	403	395	387	379	371	363	355	347	339	331	323	315	307	299	291	283
57.6	476	468	460	452	444	436	428	420	412	404	396	388	380	372	364	356	348	340	332	324	316	308	300	292	284
57.7	478	470	462	454	446	438	430	422	414	406	398	390	382	374	366	358	350	342	334	326	318	310	302	294	286
57.8	479	471	463	455	447	439	431	423	415	407	399	391	383	375	367	359	351	343	335	327	319	311	303	295	287
57.9	481	473	465	457	449	441	433	425	417	409	401	393	385	377	369	361	353	345	337	329	321	313	305	297	289
58.0	482	474	466	458	450	442	434	426	418	410	402	394	386	378	370	362	354	346	338	330	322	314	306	298	290
58.1	483	475	467	459	451	443	435	427	419	411	403	395	387	379	371	363	355	347	339	331	323	315	307	299	291
58.2	485	477	469	461	453	445	437	429	421	413	405	397	389	381	373	365	357	349	341	333	325	317	309	301	293
58.3	487	479	471	463	455	447	439	431	423	415	407	399	391	383	375	367	359	351	343	335	327	319	311	303	295
58.4	488	480	472	464	456	448	440	432	424	416	408	400	392	384	376	368	360	352	344	336	328	320	312	304	296
58.5	490	482	474	466	458	450	442	434	426	418	410	402	394	386	378	370	362	354	346	338	330	322	314	306	298
58.6	492	484	476	468	460	452	444	436	428	420	412	404	396	388	380	372	364	356	348	340	332	324	316	308	300
58.7	494	486	478	470	462	454	446	438	430	422	414	406	398	390	382	374	366	358	350	342	334	326	318	310	302
58.8	495	487	479	471	463	455	447	439	431	423	415	407	399	391	383	375	367	359	351	343	335	327	319	311	303
58.9	497	489	471	473	465	457	449	441	433	425	417	409	401	393	385	377	369	361	353	345	337	329	321	313	305
59.0	499	491	483	475	467	459	451	443	435	427	419	411	403	395	387	379	371	363	355	347	339	331	323	315	307
59.1	501	493	485	477	469	461	453	445	437	429	421	413	405	397	389	381	373	365	357	349	341	333	325	317	309
59.2	503	495	487	479	471	463	455	447	439	431	423	415	407	399	391	383	375	367	359	351	343	335	327	319	311
59.3	504	496	488	480	472	464	456	448	440	432	424	416	408	400	392	384	376	368	360	352	344	336	328	320	312
59.4	506	498	490	482	474	466	458	450	442	434	426	418	410	402	394	386	378	370	362	354	346	338	330	322	314
59.5	508	500	492	484	476	468	460	452	444	436	428	420	412	404	396	388	380	372	364	356	348	340	332	324	316
59.6	510	502	494	486	478	470	462	454	446	438	430	422	414	406	398	388	382	374	366	358	350	342	334	326	318
59.7	512	504	496	488	480	472	464	456	448	440	432	424	416	408	400	392	384	376	368	360	352	344	336	328	320
59.8	513	505	497	489	481	473	465	457	449	441	433	425	417	409	401	393	385	377	369	361	353	345	337	329	321
59.9	515	507	499	491	483	475	467	459	451	443	435	427	419	411	403	395	387	379	371	363	355	347	339	331	323
60.0	517	509	501	493	485	477	469	461	453	445	437	429	421	413	405	397	389	381	373	365	357	349	341	333	325

TABLE 9.—Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T - t'$), ° F.—Continued.

WET BULB 60.1° TO 64°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
60.1.....	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.359	0.351	0.343	0.335	0.327
60.2.....	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.401	0.393	0.385	0.377	0.369	0.361	0.353	0.345	0.337	0.329
60.3.....	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371	0.363	0.355	0.347	0.339	0.331
60.4.....	0.524	0.516	0.508	0.500	0.492	0.484	0.476	0.468	0.460	0.452	0.444	0.436	0.428	0.420	0.412	0.404	0.396	0.388	0.380	0.372	0.364	0.356	0.348	0.340	0.332
60.5.....	0.526	0.518	0.510	0.502	0.494	0.486	0.478	0.470	0.462	0.454	0.446	0.438	0.430	0.422	0.414	0.406	0.398	0.390	0.382	0.374	0.366	0.358	0.350	0.342	0.334
60.6.....	0.528	0.520	0.512	0.504	0.496	0.488	0.480	0.472	0.464	0.456	0.448	0.440	0.432	0.424	0.416	0.408	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344	0.336
60.7.....	0.530	0.522	0.514	0.506	0.498	0.490	0.482	0.474	0.466	0.458	0.450	0.442	0.434	0.426	0.418	0.410	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346	0.338
60.8.....	0.532	0.524	0.516	0.508	0.500	0.492	0.484	0.476	0.468	0.460	0.452	0.444	0.436	0.428	0.420	0.412	0.404	0.396	0.388	0.380	0.372	0.364	0.356	0.348	0.340
60.9.....	0.534	0.526	0.518	0.510	0.502	0.494	0.486	0.478	0.470	0.462	0.454	0.446	0.438	0.430	0.422	0.414	0.406	0.398	0.390	0.382	0.374	0.366	0.358	0.350	0.342
61.0.....	0.536	0.528	0.520	0.512	0.504	0.496	0.488	0.480	0.472	0.464	0.456	0.448	0.440	0.432	0.424	0.416	0.408	0.400	0.392	0.384	0.376	0.368	0.360	0.352	0.344
61.1.....	0.538	0.530	0.522	0.514	0.506	0.498	0.490	0.482	0.474	0.466	0.458	0.450	0.442	0.434	0.426	0.418	0.410	0.402	0.394	0.386	0.378	0.370	0.362	0.354	0.346
61.2.....	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371	0.363	0.355	0.347
61.3.....	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.405	0.397	0.389	0.381	0.373	0.365	0.357	0.349
61.4.....	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.359	0.351
61.5.....	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.401	0.393	0.385	0.377	0.369	0.361	0.353
61.6.....	0.547	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371	0.363	0.355
61.7.....	0.549	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.405	0.397	0.389	0.381	0.373	0.365	0.357
61.8.....	0.551	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.359
61.9.....	0.553	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.401	0.393	0.385	0.377	0.369	0.361
62.0.....	0.555	0.547	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371	0.363
62.1.....	0.557	0.549	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.405	0.397	0.389	0.381	0.373	0.365
62.2.....	0.559	0.551	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367
62.3.....	0.561	0.553	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.401	0.393	0.385	0.377	0.369
62.4.....	0.563	0.555	0.547	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379	0.371
62.5.....	0.565	0.557	0.549	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.405	0.397	0.389	0.381	0.373
62.6.....	0.567	0.559	0.551	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375
62.7.....	0.569	0.561	0.553	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.401	0.393	0.385	0.377
62.8.....	0.571	0.563	0.555	0.547	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387	0.379
62.9.....	0.573	0.565	0.557	0.549	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.405	0.397	0.389	0.381
63.0.....	0.575	0.567	0.559	0.551	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.399	0.391	0.383
63.1.....	0.577	0.569	0.561	0.553	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.401	0.393	0.385
63.2.....	0.579	0.571	0.563	0.555	0.547	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395	0.387
63.3.....	0.581	0.573	0.565	0.557	0.549	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.405	0.397	0.389
63.4.....	0.583	0.575	0.567	0.559	0.551	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.399	0.391
63.5.....	0.585	0.577	0.569	0.561	0.553	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.401	0.393
63.6.....	0.587	0.579	0.571	0.563	0.555	0.547	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.403	0.395
63.7.....	0.589	0.581	0.573	0.565	0.557	0.549	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.405	0.396
63.8.....	0.591	0.583	0.575	0.567	0.559	0.551	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.407	0.398
63.9.....	0.593	0.585	0.577	0.569	0.561	0.553	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.409	0.400
64.0.....	0.595	0.587	0.579	0.571	0.563	0.555	0.547	0.539	0.531	0.523	0.515	0.507	0.499	0.491	0.483	0.475	0.467	0.459	0.451	0.443	0.435	0.427	0.419	0.411	0.402

TABLE 9.—Vapor pressure, inches; barometer 21.42 inches; depression of wet bulb ($T-t'$), ° F—Continued.

WET BULB 64.1° TO 55°.

Wet bulb.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
64.1.....	0.597	0.589	0.581	0.573	0.565	0.558	0.549	0.541	0.533	0.525	0.517	0.509	0.501	0.493	0.485	0.477	0.469	0.461	0.453	0.445	0.437	0.429	0.421	0.413	0.404
64.2.....	0.599	0.591	0.583	0.575	0.567	0.559	0.551	0.543	0.535	0.527	0.519	0.511	0.503	0.495	0.487	0.479	0.471	0.463	0.455	0.447	0.439	0.431	0.423	0.415	0.406
64.3.....	0.601	0.593	0.585	0.577	0.569	0.561	0.553	0.545	0.537	0.529	0.521	0.513	0.505	0.497	0.489	0.481	0.473	0.465	0.457	0.449	0.441	0.433	0.425	0.417	0.408
64.4.....	0.604	0.596	0.588	0.580	0.572	0.564	0.556	0.548	0.540	0.532	0.524	0.516	0.508	0.500	0.492	0.484	0.476	0.468	0.460	0.452	0.444	0.436	0.428	0.420	0.411
64.5.....	0.606	0.598	0.590	0.582	0.574	0.566	0.558	0.550	0.542	0.534	0.526	0.518	0.510	0.502	0.494	0.486	0.478	0.470	0.462	0.454	0.445	0.437	0.429	0.421	0.413
64.6.....	0.608	0.600	0.592	0.584	0.576	0.568	0.560	0.552	0.544	0.536	0.528	0.520	0.512	0.504	0.496	0.488	0.480	0.472	0.464	0.456	0.447	0.439	0.431	0.423	0.415
64.7.....	0.610	0.602	0.594	0.586	0.578	0.570	0.562	0.554	0.546	0.538	0.530	0.522	0.514	0.506	0.498	0.490	0.482	0.474	0.466	0.458	0.449	0.441	0.433	0.425	0.417
64.8.....	0.612	0.604	0.596	0.588	0.580	0.572	0.564	0.556	0.548	0.540	0.532	0.524	0.516	0.508	0.500	0.492	0.484	0.476	0.468	0.460	0.451	0.443	0.435	0.427	0.419
64.9.....	0.614	0.606	0.598	0.590	0.582	0.574	0.566	0.558	0.550	0.542	0.534	0.526	0.518	0.510	0.502	0.494	0.486	0.478	0.470	0.462	0.453	0.445	0.437	0.429	0.421
65.0.....	0.616	0.608	0.600	0.592	0.584	0.576	0.568	0.560	0.552	0.544	0.536	0.528	0.520	0.512	0.504	0.496	0.488	0.480	0.472	0.464	0.455	0.447	0.439	0.431	0.423

APPENDIX B.

TABLE 10.—*Osmotic pressure in atmospheres for depression of the freezing point to 2.999° C.¹*

	0	1	2	3	4	5	6	7	8	9
0.0.....	0.000	0.121	0.241	0.362	0.482	0.603	0.724	0.844	0.965	1.085
0.1.....	1.206	1.327	1.447	1.568	1.688	1.809	1.930	2.050	2.171	2.291
0.2.....	2.412	2.532	2.652	2.772	2.893	3.014	3.134	3.255	3.375	3.496
0.3.....	3.616	3.737	3.857	3.978	4.098	4.219	4.339	4.459	4.580	4.700
0.4.....	4.821	4.941	5.062	5.182	5.302	5.423	5.543	5.664	5.784	5.904
0.5.....	6.025	6.145	6.266	6.386	6.506	6.628	6.747	6.867	6.988	7.108
0.6.....	7.229	7.349	7.469	7.590	7.710	7.830	7.951	8.071	8.191	8.312
0.7.....	8.432	8.552	8.672	8.793	8.913	9.033	9.154	9.274	9.394	9.514
0.8.....	9.635	9.755	9.875	9.995	10.12	10.24	10.36	10.48	10.60	10.72
0.9.....	10.84	10.96	11.08	11.20	11.32	11.44	11.56	11.68	11.80	11.92
1.0.....	12.04	12.16	12.28	12.40	12.52	12.64	12.76	12.88	13.00	13.12
1.1.....	13.24	13.36	13.48	13.60	13.72	13.84	13.96	14.08	14.20	14.32
1.2.....	14.44	14.56	14.68	14.80	14.92	15.04	15.16	15.28	15.40	15.52
1.3.....	15.64	15.76	15.88	16.00	16.12	16.24	16.36	16.48	16.60	16.72
1.4.....	16.84	16.96	17.08	17.20	17.32	17.44	17.56	17.68	17.80	17.92
1.5.....	18.04	18.16	18.28	18.40	18.52	18.64	18.76	18.88	19.00	19.12
1.6.....	19.24	19.36	19.48	19.60	19.72	19.84	19.96	20.08	20.20	20.32
1.7.....	20.44	20.56	20.68	20.80	20.92	21.04	21.16	21.28	21.40	21.52
1.8.....	21.64	21.76	21.88	22.00	22.12	22.24	22.36	22.48	22.60	22.72
1.9.....	22.84	22.96	23.08	23.20	23.32	23.44	23.56	23.68	23.80	23.92
2.0.....	24.04	24.16	24.28	24.40	24.52	24.63	24.75	24.87	24.99	25.11
2.1.....	25.23	25.35	25.47	25.59	25.71	25.83	25.95	26.07	26.19	26.31
2.2.....	26.43	26.55	26.67	26.79	26.91	27.03	27.15	27.27	27.39	27.51
2.3.....	27.63	27.75	27.87	27.99	28.11	28.23	28.34	28.46	28.58	28.70
2.4.....	28.82	28.94	29.06	29.18	29.30	29.42	29.54	29.66	29.78	29.90
2.5.....	30.02	30.14	30.26	30.38	30.50	30.62	30.74	30.86	30.98	31.09
2.6.....	31.21	31.33	31.45	31.57	31.69	31.81	31.93	32.05	32.17	32.29
2.7.....	32.41	32.55	32.65	32.77	32.89	33.01	33.13	33.25	33.36	33.48
2.8.....	33.60	33.72	33.84	33.96	34.08	34.20	34.31	34.43	34.56	34.68
2.9.....	34.79	34.91	35.04	35.16	35.27	35.39	35.51	35.63	35.75	35.87

¹ Harris, J. A., and Gortner, R. A., Amer. Jour. Botany, 1: 75-78, 1914.TABLE 11.—*An extension to 5.99° of tables to determine the osmotic pressure of expressed vegetable saps from the depression of the freezing point.¹*

[Hundredths of degrees, centigrade.]

	0	1	2	3	4	5	6	7	8	9
3.0.....	35.99	36.11	36.23	36.35	36.47	36.59	36.71	36.83	36.95	37.06
3.1.....	37.18	37.30	37.42	37.54	37.66	37.78	37.90	38.02	38.14	38.26
3.2.....	38.38	38.50	38.62	38.73	38.85	38.97	39.09	39.21	39.33	39.45
3.3.....	39.57	39.69	39.81	39.93	40.05	40.17	40.28	40.40	40.52	40.64
3.4.....	40.76	40.88	41.00	41.12	41.24	41.36	41.48	41.60	41.71	41.83
3.5.....	41.95	42.07	42.19	42.31	42.43	42.55	42.67	42.79	42.91	43.02
3.6.....	43.14	43.26	43.38	43.50	43.62	43.74	43.86	43.98	44.10	44.22
3.7.....	44.33	44.45	44.57	44.69	44.81	44.93	45.05	45.17	45.29	45.41
3.8.....	45.52	45.64	45.76	45.88	46.00	46.12	46.24	46.36	46.48	46.60
3.9.....	46.71	46.83	46.95	47.07	47.19	47.31	47.43	47.55	47.67	47.79
4.0.....	47.90	48.02	48.14	48.26	48.38	48.50	48.62	48.74	48.86	48.97
4.1.....	49.09	49.21	49.33	49.45	49.57	49.69	49.81	49.93	50.04	50.16
4.2.....	50.28	50.40	50.52	50.64	50.76	50.88	50.99	51.11	51.23	51.35
4.3.....	51.47	51.59	51.71	51.83	51.94	52.06	52.18	52.30	52.42	52.54
4.4.....	52.66	52.78	52.89	53.01	53.13	53.25	53.37	53.49	53.61	53.73
4.5.....	53.84	53.96	54.08	54.20	54.32	54.44	54.56	54.68	54.79	54.91
4.6.....	55.03	55.15	55.27	55.39	55.51	55.62	55.74	55.86	55.98	56.10
4.7.....	56.22	56.34	56.46	56.57	56.69	56.81	56.93	57.05	57.17	57.29
4.8.....	57.40	57.52	57.64	57.76	57.88	58.00	58.12	58.23	58.35	58.47
4.9.....	58.59	58.71	58.83	58.95	59.06	59.18	59.30	59.42	59.54	59.66
5.0.....	59.78	59.89	60.01	60.13	60.25	60.37	60.49	60.60	60.72	60.84
5.1.....	60.96	61.08	61.20	61.32	61.43	61.55	61.67	61.79	61.91	62.03
5.2.....	62.14	62.26	62.38	62.50	62.62	62.74	62.85	62.97	63.09	63.21
5.3.....	63.33	63.45	63.56	63.68	63.80	63.92	64.04	64.16	64.27	64.39
5.4.....	64.51	64.63	64.75	64.87	64.98	65.10	65.22	65.34	65.46	65.58
5.5.....	65.69	65.81	65.93	66.05	66.17	66.29	66.40	66.52	66.64	66.76
5.6.....	66.88	67.00	67.11	67.23	67.35	67.47	67.59	67.71	67.82	67.94
5.7.....	68.06	68.18	68.30	68.41	68.53	68.65	68.77	68.89	69.01	69.12
5.8.....	69.24	69.36	69.48	69.60	69.71	69.83	69.95	70.07	70.19	70.30
5.9.....	70.42	70.54	70.66	70.78	70.90	71.01	71.13	71.25	71.37	71.49

¹ Harris, J. A., Amer. Jour. of Botany, 2: 418-419, 1915.

APPENDIX C.

STANDARD TITRATION METHODS FOR SOIL ACIDITY AND FOR CARBONATES
("BLACK ALKALI").

The following procedure in titration for the alkalinity and acidity tests is practically that followed by the Bureau of Soils, and a number of soil departments in the agricultural experiment stations:

The equipment required¹ is two 50-cubic centimeter burette titration apparatuses, one 50-cubic centimeter graduate, one 250-cubic centimeter graduate, two 50-cubic centimeter Nessler tubes, 1-liter flask, four 100-cubic centimeter beakers, two 50-cubic centimeters Royal Berlin porcelain evaporating dishes, one 50-cubic centimeter pipette, two ordinary pipettes or droppers, bottles and jars for reagents, analytical balance, numerous quart jars with screw caps or stoppers, and reagents as indicated by the procedure. The necessary reagents are prepared as follows:

(1.) Standard Potassium hydrogen sulphate solution:

The average single test will not require over 5 cubic centimeters of this solution. Dissolve 5.58 grams of pure KHSO_4 in 1 liter of water, and dilute 100 cubic centimeters of this solution to 1 liter. Place the dilute solution in burette jar No. 1, for alkalinity titrations.

(2.) Phenolphthalein indicator:

A drop or two for each alkalinity and acidity test is required. Dissolve 1 gram of phenolphthalein in 100 cubic centimeters of 50 per cent alcohol. Neutralize by adding a few drops of centinormal alkali, until faintly red, then add a drop of centinormal acid, which should remove the color.

(3.) Methyl orange indicator:

A drop or two for each alkalinity test is required. Dissolve 1 gram of methyl orange (indicator) in 1 liter distilled water.

(4.) Normal alkali is prepared by dissolving 39.96 grams of NaOH in 1 liter of water. Since only a few drops of the centinormal solution are needed in preparing the phenolphthalein indicator, and the exact strength is unimportant, use in about the proportion of 0.04 gram per 100 cubic centimeter of water.(5.) Centinormal acid (HCl):

Exact strength unimportant. About 2 drops in 100 cubic centimeters of water give approximately correct strength.

(6.) Standard sodium hydroxide solution:

Compute quantity required at rate of one-half to 1 cubic centimeter per acidity test made. The solution is not normal, but is computed so that 1 cubic centimeter will have the equivalent value of 4 mg. of calcium. Dissolve 6.4 grams of pure NaOH in 1 liter of freshly boiled distilled water. Place this in burette jar No. 2, for acidity titrations. Exclude air from the jar as far as possible and make-up fresh solution frequently.

(7.) Normal potassium nitrate solution:

Use 250 cubic centimeters for each soil examined for acidity. Dissolve 100.93 grams of pure KNO_3 in 1 liter of distilled water.

ALKALINITY TEST.

Place 100 grams of air-dried soil of the sample to be examined in a quart jar; add 200 cubic centimeters of distilled water; shake occasionally during

¹ The special equipment required to conduct the work at experiment stations should cost approximately \$20 to \$25.

12 hours and allow to settle. The test may best be started early in the day, shaking jars occasionally during the day and leaving them to settle overnight. Turbidity of the solution is difficult to eliminate in this test, but time is saved if complete settling occurs.

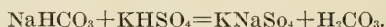
Draw off with pipette 50 cubic centimeters of the supernatant liquid; filter, if not fairly clear, into an evaporating dish; and evaporate over Bunsen flame, continuing the drying almost to red heat, so that residue is devoid of humus and will cling together in flakes when the dish is scraped. When dish is cool add 50 cubic centimeters of distilled water; allow to stand for two hours; then pour half of solution into each of two 50-cubic centimeter Nessler tubes. If fusing of residue has been complete, filtering at this stage would be unnecessary, as the flakes of solid matter will remain in evaporating dish.

Add to each Nessler tube a drop of phenolphthalein indicator, comparing the first tube with that which has not been treated, before treating the second. If the solution in tube 1 is colored pink, carbonate (Na_2CO_3) is present, and the solution is titrated with KHSO_4 until pink color disappears. The burette, presumably graduated to tenths of a cubic centimeter, should be estimated to the nearest hundredth just before beginning to titrate, and again as soon as the color disappears. The comparison tube may then be similarly treated, reading the burette for the second treatment, as a check on the first. This second tube is carried simply as a color comparator.

A drop of methyl orange indicator is now added to each of the above tubes, whether or not the titration for carbonate has been made. This will give to each a yellow color, and the second tube will be kept alongside the one which is titrated so that change of color in the latter will be quickly apparent. The titration of the first tube is continued until the slightest reddish or orange tinge appears. This may best be discerned against a white background and not in direct sunlight, which sometimes itself imparts a reddish tinge to the yellowish solution. A final reading of the burette is obtained to compute the quantity of KHSO_4 used in titrating for the bicarbonate (NaHCO_3).

The amount of the second titration, less the amount of the first, gives the amount necessary to neutralize the HCO_3 originally present, since the first reaction changed the carbonate to bicarbonate, as follows: $\text{Na}_2\text{CO}_3 + \text{KHSO}_4 = \text{KNaSO}_4 + \text{NaHCO}_3$.

The second titration, or the first if no carbonate was originally present, reduces all bicarbonate present to carbonic acid, as shown by the reaction:



For each 0.01 cubic centimeter of KHSO_4 used in the first titration, there was present 0.00246 milligram of CO_2 in the 25 cubic centimeter solution treated, or 0.01968 milligram in the solution representing 100 grams of soil, or 0.00001968 per cent of the soil weight.

For each 0.01 cubic centimeter of KHSO_4 in the differential titration, there was present in the original solution 0.0025 mg. of HCO_3 in the 25 cubic centimeter solution used, or 0.02 mg. in the solution representing 100 grams of soil, or 0.00002 per cent of the weight of the soil.

ACIDITY TEST.

Place 100 grams of air-dried soil of the sample to be tested in a quart jar; add 250 cubic centimeters of normal KNO_3 solution and stopper; and shake at intervals of 5 minutes for 3 hours. Let stand overnight. Draw off 125 cubic centimeters of the supernatant liquid, which in this case is usually quite clear; boil 10 minutes to expel carbon dioxide; cool; and add a drop of phenolphthalein

indicator. Place the beaker under the burette, against a white background, and titrate with NaOH to the appearance of the faintest pink color.

The amount of the titration being determined by readings of the burette, the amount of acid present in the solution is expressed by the amount of lime which would be required to neutralize it. Each 0.01 cubic centimeter of the sodium hydroxide used in titration is equivalent to 0.04 mg. of calcium carbonate in the 125 cubic centimeter solution used, and while this stands for one-half of the 100 grams of soil treated, it really stands for only two-fifths of the acid in that soil, because the first solution does not completely dissolve the acids. Therefore, each 0.01 cubic centimeter of titration indicates 0.1 mg. of lime necessary to neutralize the 100 grams of soil, or the amount required to neutralize is 0.0001 per cent of soil weight.

In practice, the amount of lime required to neutralize the first foot of soil is expressed in tons per acre, being computed, of course, on a standard or specific weight of soil per acre-foot.

Space is provided on "Summary of Physical and Chemical Properties of Soil" form for tabulating the computed results of alkalinity and acidity tests in terms of percentages of the weight of soil, which are as serviceable for scientific comparisons as any other expression.

LIST OF REFERENCES.

The following citations to the literature of forest ecology are mainly those concerned with methodology. A few references are given to descriptive works in which the methods of obtaining the results are clearly brought out, or in which the nature of the problem to be met by the future ecologist is emphasized. No attempt has been made to prepare a complete bibliography, and the convenience of the average student has received considerable weight, in avoiding, especially, foreign language articles.

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TWO MAGNIFICENT SPECIMENS OF SPRUCE IN ALASKA.



SITKA SPRUCE: ITS USES, GROWTH, AND MANAGEMENT.

By N. LEROY CARY, *Forest Examiner.*

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INTRODUCTION.

Sitka spruce (*Picea sitchensis* (Bong.) Trautv. and Mayer), also called tideland spruce, is an important timber tree of the Pacific coast region, growing naturally from Alaska to northern California. It is found largely at low altitudes and never very far from the ocean. In Alaska it is the principal tree of commerce; in Oregon and Washington it is one of the components of the dense and luxuriant coniferous forest that blankets the humid strip of country on the west side of the coastal ranges. Here several of its associate trees are more abundant than Sitka spruce; but in the superior qualities of its wood, in its magnificent form, and in its immense size it has no superior except the redwood with which it mixes at the south end of its range.

Because Sitka spruce does not ordinarily occur in pure stands, it must be logged in conjunction with other timber species—with Douglas fir, western hemlock, and western red cedar in Washington and Oregon, and with the western hemlock in Alaska. The greater part of the virgin forests in which Sitka spruce occurs has not been

NOTE.—The writer wishes to acknowledge the valuable assistance given him by Messrs. H. T. Gisborne, R. H. Weldman, and others in the preparation of this manuscript.

reached by lumbering operations; hence until recently the cut of this timber had been relatively small. It was not well known in the world or national markets until an extraordinary demand for it arose during the war because its wood was found to be superior for airplane construction. Within the space of a few months in 1917 this species, which had been of decidedly secondary importance in the lumber industry, became one of the woods most eagerly sought. To effect an enormous increase in the production of Sitka spruce and to obtain lumber of the quality needed for airplane wing beams, a special organization of the War Department—the Spruce Production Division—was created. The great activity of this organization in promoting the lumbering of this needed Sitka spruce airplane stock in conjunction with the local lumber industry is one of the interesting chapters in the history of the war industries.¹

Although Sitka spruce may never again be so eagerly sought and so extensively cut as during the war, it has so many superior qualities in the estimation of foresters and lumbermen that it will always play an important rôle in the forest management of the Pacific coast region. It has a habit of rapid growth, makes a large yield per acre, lends itself fairly well to forest management, and produces a wood which has large value for many special purposes, prominent among which is the manufacture of paper.

GEOGRAPHIC DISTRIBUTION AND ALTITUDINAL RANGE.

The botanical range of Sitka spruce, as shown in figure 1, lies along the north Pacific coast, roughly between 40° and 60° of latitude, and in that narrow strip of shore line often described as the fog belt. Its width is nowhere more than 200 miles from the coast line eastward, and usually much less.

In Alaska this species occurs as far north as the west shore of Cook Inlet, the north end of Kodiak Island, and along the Lynn Canal, and is generally abundant southward, on the islands and mainland near the coast of southeastern Alaska. In British Columbia it is found chiefly along the shore line and on the lowlands of the large rivers like the Fraser.

In the United States it is found in the western part of the State of Washington on the lower benches and bottomlands of the rivers along the Pacific coast, and less commonly about Puget Sound, occurring sporadically in the foothills of the Cascade Range. In Oregon it is found under similar conditions but almost exclusively west of the crest of the Coast Range; it extends up the Columbia River only 50 miles from its mouth, and farther south not more than

¹ "History of Spruce Production Division, United States Army," issued by the United States Spruce Production Corporation.

20 miles inland. In California it grows close to the shore line and along the Smith and Klamath Rivers; the southern limit of its range is near Casper, in Mendocino County.

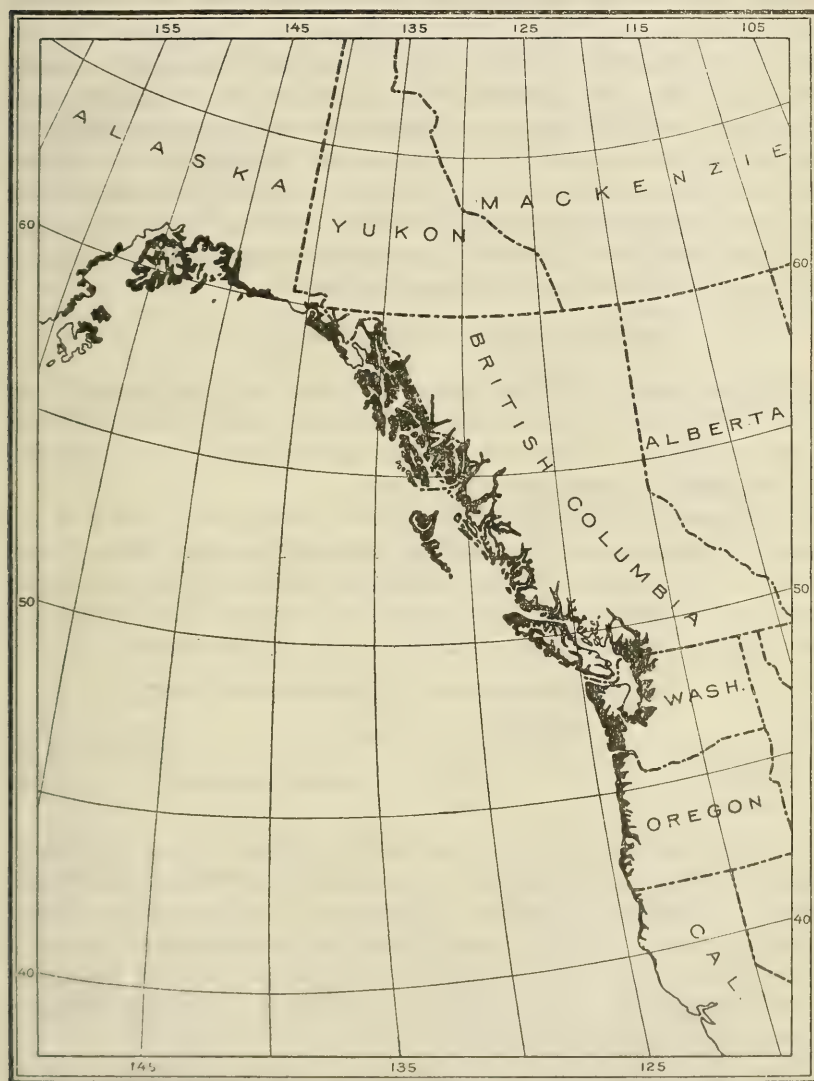


FIG. 1.—Botanical distribution of Sitka spruce, shown by shaded areas.

Heavy commercial stands of this species are found all the way from southeastern Alaska to Coos Bay, Oreg., though by no means does this tree preponderate in the forest growth throughout this strip nor is it even present everywhere. The heaviest stands of Sitka spruce, in its entire range, occur in the northwestern part of the

Olympic Peninsula (Washington) along the Soleduck, Dickey, and Hoko Rivers at elevations between 400 and 600 feet.

The upper altitudinal limit has been noted by many observers as being higher in the northern part of its range than farther south; it is seldom, however, more than 3,000 feet above sea level. In the States it is doubtful whether it grows at that elevation; actually it has been found at 2,500 feet on the west side of the Olympic Mountains, at 2,100 feet near Bandera in the Cascade Range of Washington, and at about 2,100 feet on the slopes of Saddle Mountain in Clatsop County, Oreg. (Pl. I.) Although botanically it does occur at these elevations, an altitude of about 1,200 feet marks the upper limit of its growth in commercial quantities. The lower limit extends to the very surf line of the Pacific.

PRESENT SUPPLY AND ANNUAL CUT.

The total stand of Sitka spruce in America is estimated at 40 to 44 billion feet. As shown in Table 1, more than one-third occurs in Alaska, one-third in British Columbia, and the remainder in Washington, Oregon, and California.

It is estimated that about 1,600 million board feet of the most accessible spruce has been cut since the estimates given in Table 1 were made.² An additional billion board feet is estimated to have blown down by the catastrophic wind storm of January, 1921, which occurred in the heart of the Sitka spruce belt of Washington.

TABLE 1.—*Estimated stand of Sitka spruce in 1918.*³

State:	Million feet b. m.	State:	Million feet b. m.
Washington -----	6,575	Alaska -----	15,000 to 18,000
Oregon -----	4,374	British Columbia -----	15,186
California -----	187		

Sitka spruce forms only 1.5 per cent by volume of the total merchantable stand of timber west of the Cascades in Oregon and Washington. In British Columbia it comprises 6.7 per cent of the timber along the coast. Of the coastal forests of southeastern Alaska it forms about 20 per cent. Approximately 50 per cent of the entire stand of Sitka spruce is in private ownership. Detailed estimates of ownership appear in Table 10.

The cut of spruce in Washington and Oregon increased over 50 per cent in the year 1918, and practically all of this increase was made up of Sitka spruce. The cut of spruce in the United States increased very little, and in general is declining. For a number of

² "Supplies and Production of Aircraft Woods," by W. N. Sparhawk, National Advisory Committee for Aeronautics, Fifth Annual Report. Rpt. 67, p. 9, 1919.

³ Figures for all localities except British Columbia compiled by Forest Service from county records and private, State, and Government estimates. British Columbia figures from "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 330, 1918.

years Maine had been the leading spruce-producing State, cutting chiefly red spruce; but the pressing need for spruce aircraft lumber for war uses stimulated production in the Pacific Northwest to such an extent that in 1918 Washington took first place in the production of spruce with a cut of over 275,000,000 board feet, Oregon second with a cut of over 215,000,000, while Maine dropped to third place. As is shown in detail in Table 2, the cut of spruce for 1918 comprised 6 and 8 per cent, respectively, of the total lumber production in Washington and Oregon, less than 2 per cent in California, and practically the entire cut in Alaska. No distinction is made between species of spruce, but Sitka spruce probably forms over 95 per cent in these three States. In British Columbia the ratio was about the same as in Washington. The total cut of Sitka spruce in 1918, exclusive of British Columbia, exceeded 536,000,000 board feet.

TABLE 2.—*Total reported cut of spruce lumber, 1915-1918.*

[No distinction is made between species of spruce: Sitka spruce probably forms over 95 per cent in Washington, Oregon, and California.]

Year.	Number of active mills reporting.	Quantity of spruce reported cut.	Per cent of total lumber cut.	Per cent of total spruce cut in United States.	Average value per 1,000 feet f. o. b. mill.
		<i>M feet. b. m.</i>			
Washington:					
1915 ¹	49	196, 203	5.3	16.4	\$14.08
1916 ²	65	221, 295	5.0	19.6	14.08
1917 ³	66	198, 271	4.6	20.3	22.34
1918 ⁴	60	275, 826	6.0	28.1	23.91
Oregon:					
1915 ¹	20	65, 327	4.3	5.5	13.56
1916 ²	23	96, 245	4.3	8.5	11.96
1917 ³	26	120, 647	4.9	12.3	28.28
1918 ⁴	35	215, 828	8.0	22.0	27.03
California:					
1915 ¹		9, 477	0.8		
1916 ²	2	13, 871	0.9	1.2	14.44
1917 ³	4	20, 659	1.5	2.1	17.50
1918 ⁴	8	16, 663	1.3	1.7	20.75
Alaska: 1918 ⁵	18	28, 716	98.0		23.00
British Columbia:					
1915 ⁶	49	7 56, 360			13.60 ⁷
1916 ⁶	48	7 49, 077	5.6		14.66

¹ "Production of Lumber, Lath, and Shingles in 1915 and Lumber in 1914," U. S. Dept. Agr. Bul. 506, p. 20.

² "Production of Lumber, Lath, and Shingles in 1916," U. S. Dept. Agr. Bul. 673, p. 21.

³ "Production of Lumber, Lath, and Shingles in 1917," U. S. Dept. Agr. Bul. 768, p. 21.

⁴ "Production of Lumber, Lath, and Shingles in 1918," U. S. Dept. Agr. Bul. 845, p. 24.

⁵ "Character and Distribution of the 1918 Lumber and Shingle Cut of Washington, Oregon, and Alaska, by Producing and Consuming Regions," by T. J. Starker, West Coast Lumberman, Vol. 36, No. 423, p. 26, 1919.

⁶ "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 178, 1918.

⁷ No distinction is made between species of spruce; probably about 80 per cent Sitka spruce.

CHARACTERISTICS OF THE WOOD.

Sitka spruce wood is light, soft, straight-grained, tough, easily worked, and very strong for its weight. It is tasteless and contains very few resin ducts. The color of the heartwood is a pale pinkish brown, which blends imperceptibly into the creamy white of the

sapwood. The longitudinal surface of the wood shows a silky sheen, and the tangential surface, less noticeably, slight indentations or dimples. There is no distinct line of demarkation between the springwood and the summerwood as in Douglas fir.

Compared with other woods of similar weight, Sitka spruce is of greater strength and toughness. Table 17 (Appendix) shows the value of its mechanical properties as measured by laboratory tests. Individual test specimens may show a variation of as much as 16 per cent from the data on bending, compression, shearing, tension, and such properties.

Spiral grain is found in Sitka spruce as in other species, though not to any great extent. During the war specifications for airplane stock required that no spiral-grained wood be accepted which had more than 1 inch departure in 20 inches of length. Tests showed that a greater amount of twist caused a marked reduction in strength for aircraft purposes. Spiral grain in Sitka spruce can generally be detected in the standing tree by a twisting of the fluted portions of the lower trunk.

The calorific power of one cord of air-dried Sitka spruce wood is 52 per cent of that of a short ton of coal, and that of western hemlock and Douglas fir is 58 and 68 per cent, respectively.

USES.

The varied properties of Sitka spruce fit it for a wide variety of uses. It is the premier wood for the manufacture of aircraft. It is unsurpassed for pulp and is especially adapted for musical instruments. It is also a desirable wood for boxes, crates, barrels, veneer, and woodenware.

By far the most extensive use to which the wood is put is the manufacture of lumber. As such, in one form or another, it is used for about the same purposes as the other spruces. About 40 per cent is used for construction and similar purposes without further manufacture. While not suitable for heavy construction, it is well adapted for many building uses in which light weight, ease in working, and ability to take and hold nails and paints are essential. It is especially suitable for large doors, such as are used for garages, freight houses, and similar structures. It is extensively used for beveled siding. As a car stock it is unsurpassed. The bulk of the lumber, however, is remanufactured into a large variety of products.

More than half the lumber cut of this species is consumed by the planing mill, box, and crate industries. It cuts to advantage for doors, window and door frames, and molding. Belonging to the class of tasteless woods, Sitka spruce is extensively used for containers in which articles of food are packed or handled.

Because of its light weight, combined with strength and toughness, Sitka spruce is the most desirable and most generally used wood for such airplane parts as wing beams, struts, longerons, ribs, and plywood parts. Although red, white, and Sitka spruce do not differ greatly in strength properties, the last species, on account of its greater size and consequently its greater proportion of clear lumber, is a more important source of aircraft material than the other two. Because of this and the relatively large supplies of virgin timber still remaining, Sitka spruce will probably for many years be a very important species in the aircraft industry, notwithstanding the fact that the supply is far from the centers of manufacture.

Because of the resonant quality of the wood, its even structure, the absence of vessels, the extremely fine and regularly distributed medullary rays, and the straight and long fibers, spruce generally is considered to be the best wood for piano sounding-boards, as well as for musical instruments generally. Sitka spruce yields a large proportion of clear lumber and wood of selected quality for this purpose, but its rapid growth tends to lessen the resonant quality in comparison with the slower growing eastern species.

The wood is not durable in contact with the soil or when exposed to weather. It is less suitable for piling in salt water than are other species, because of its greater susceptibility to the ravages of the teredo, which may destroy it in one or two years.

For the manufacture of white paper pulp by either the mechanical or the chemical process, spruce is the leading wood used. It is soft, white, and nonresinous, and its fibers are longer, more flexible, and stronger than those of most woods. Containing a maximum percentage of cellulose, it gives a high yield by the chemical process. Although there are several species of spruce, no marked difference is noted in the pulps manufactured from them. A comparison of the character and uses of the pulp made from Sitka spruce with that made from white spruce, a wood that can be considered standard for pulping by the sulphite, sulphate, and mechanical processes, indicates no practical difference.

Because of the long distance to the large paper markets of the East, the utilization of Sitka spruce for paper manufacture is relatively small. Of the domestic spruce consumption in the United States in 1918 for the manufacture of paper, 35,385 cords, or 1.6 per cent, was Sitka spruce from the forests of Washington and Oregon. British Columbia utilizes about half as much Sitka spruce for this purpose as do the States of Oregon and Washington. Other species, including western hemlock, white fir, cottonwood, and Douglas fir, are utilized on the Pacific coast in the manufacture of pulp, but Sitka spruce represents about 15 per cent of the total.

The pulp, paper, and board industry of the West, a long-established one, is confined practically to the Pacific coast, with the pulp mills largely confined to the States of Oregon, Washington, and the province of British Columbia. Alaska has one pulp mill, established in 1921. There is every indication that this industry will grow rapidly in the next few years, with an abundant supply of pulp-wood, waterpower, and coal, taken in connection with the fact that the pulp-wood supply in the East is approaching depletion.

LOGGING AND MILLING.

The occurrence of Sitka spruce on the lowlands near tidewater, and along navigable or drivable rivers, on the benches and gently rolling country of the lower foothills makes logging relatively easy, and a mild climate permits year-long operation. As the species occurs largely in association with Douglas fir, hemlock, and cedar, the method of logging is identical with that universally used in the heavy forests of the Pacific coastal region. Here large operations, powerful steam machinery, and heavy capital investments are the distinctive features of logging operations. (Pl. II.) These are required by the large size of the timber, the ground conditions, and the enterprise of the industry.

Trees 6, 8, or 10 feet in diameter, standing on rough steep ground, are felled and converted into logs in such a way that the minimum of waste results; and logs, some of them scaling 10,000 feet and weighing 30 tons, are dragged with great dispatch over the ground or swung down steep slopes and over deep canyons on overhead cables. The greater part of the timber is transported from the woods to the mills or waterside over standard-gauge logging railroads for distances ranging from a few miles to 30 or more. (Pl. III.) To a limited extent motor trucks (Pl. IV) are used in conveying logs, and in some cases in the Grays Harbor and Willapa Harbor regions of Washington logs are transported by driving streams. A large percentage of the cut of Sitka spruce reaches the waterside along the Columbia River and in Puget Sound, Grays Harbor, and Willapa Harbor, where the logs are made into rafts and towed to the mills.

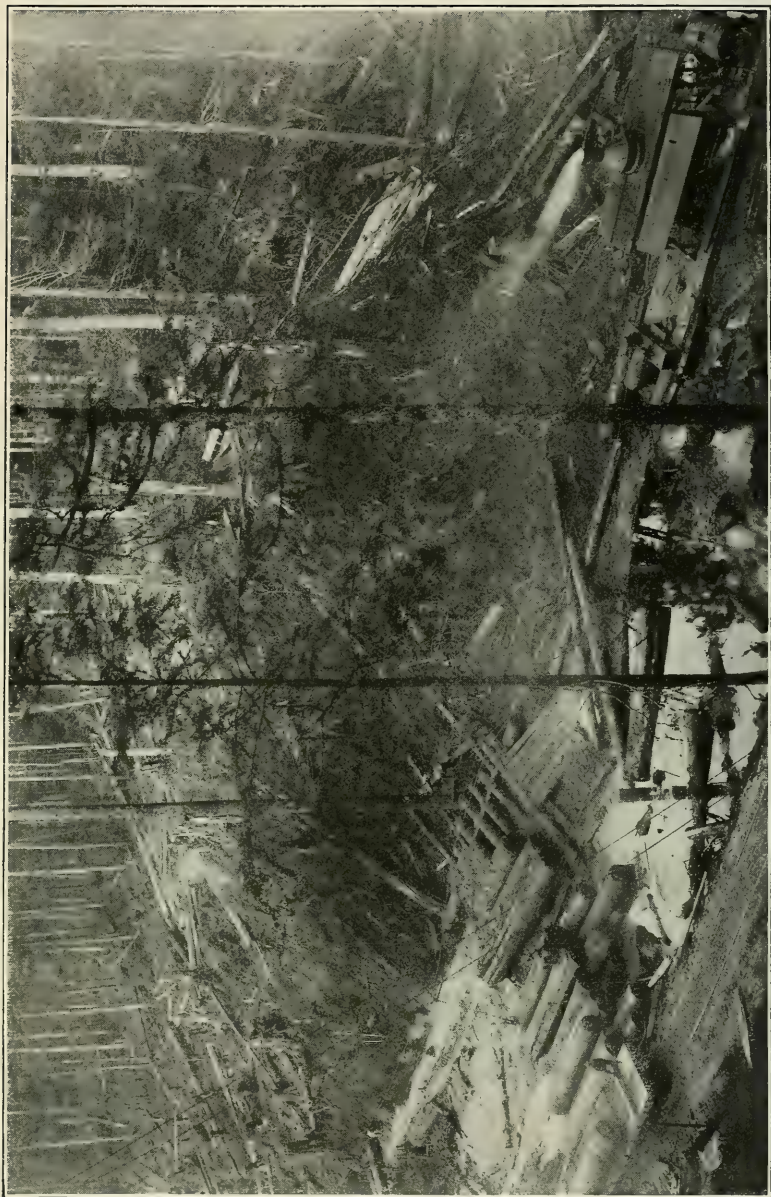
Logging with animals in Oregon and Washington is confined to small operations getting out ties, shingle bolts, piles, and poles. In Alaska, operations are found only along the shore line, and there both hand and machine methods are employed. If the latter method is used the donkey engine is mounted on a float, the hauling line is led inshore a thousand feet or more, and the logs are skidded directly to the water to be towed to the mills.

The sudden and urgent demand in 1917 for high-grade spruce timber for airplane material, which existing logging operations were



F. NICHOLS

GROUP OF SITKA SPRUCES IN CLATSOP COUNTY, OREG.



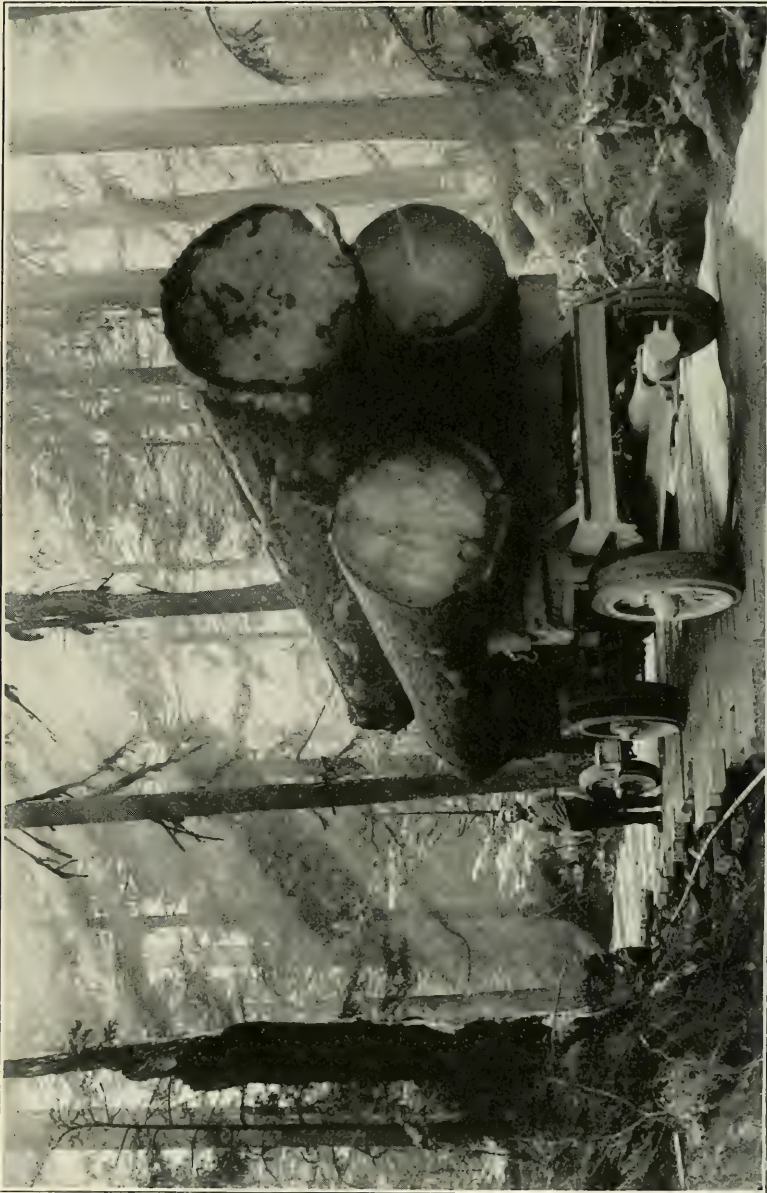
F-NIC-2

STEAM LOGGING IN SITKA SPRUCE, SHOWING DONKEY ENGINE AND LANDING.



F-NLC-3

A TRAINLOAD OF LARGE SITKA SPRUCE LOGS AT BOOMING GROUNDS.



F-NLC-4

TRANSPORTATION OF LOGS BY AUTO TRUCK.

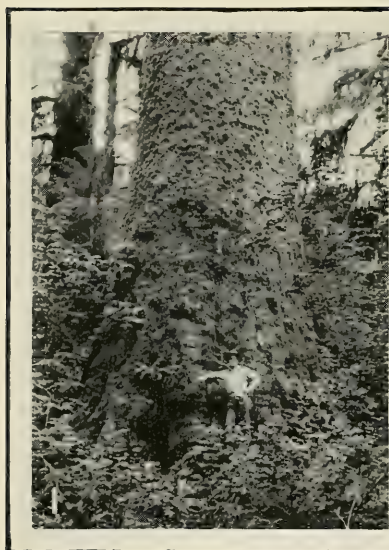


F—NLC-5



F—NLC-6

FIG. 1. RIVING FOR CLEAR AIRPLANE MATERIAL. FIG. 2. DÉBRIS AFTER SELECTIVE LOGGING.



F—S50842

FIG. 1.—LARGE SITKA SPRUCE NEAR
BEAVER, WASH., MEASURING
16 FEET IN DIAMETER.



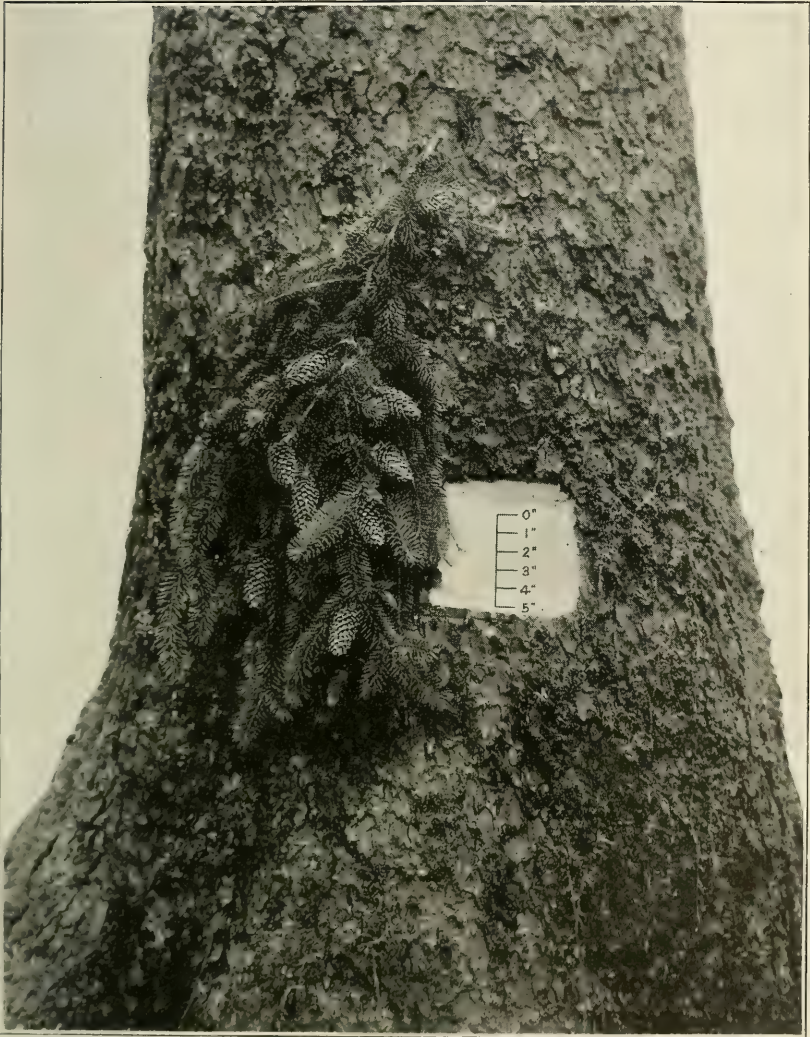
F—NLC-7

FIG. 2.—SAME AS FIGURE 1, SHOW-
ING BROKEN TOP.



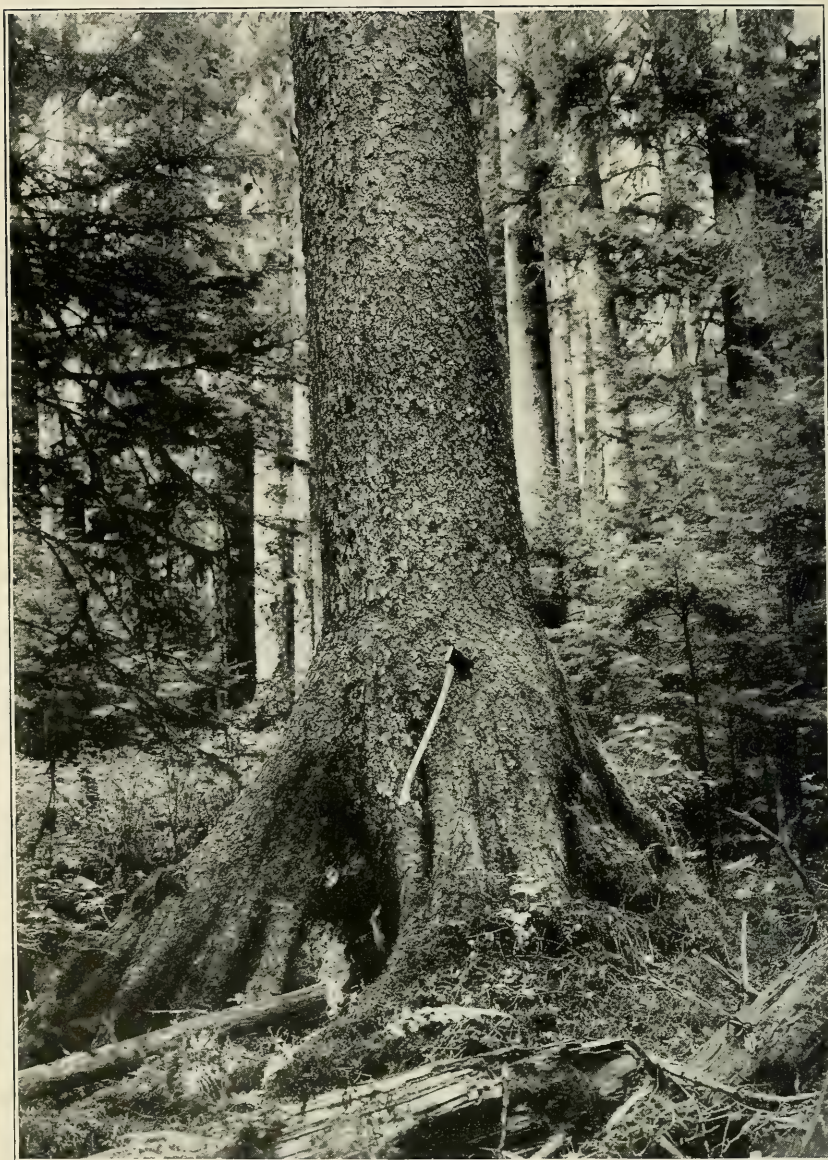
F—NLC-8

FIG. 3.—TWO BIG STUMPS IN CLATSOP COUNTY, OREG., SHOWING FLARE
OF THE ROOTS.



F-70501

TYPICAL FOLIAGE, CONES, AND BARK OF SITKA SPRUCE.



F-70502

BASAL SWELL IN SITKA SPRUCE IN ALASKA.

unable to meet, caused the Spruce Production Division to encourage small isolated operations to rive out by hand cants of clear spruce from selected trees. By means of wedges and jacks huge logs were split to obtain cants of clear, straight-grained wood, which were dragged from the woods, usually by horses, and sent to resaw plants. (Pl. V, fig. 1). That method of logging was discarded later in favor of a plan of logging selected trees on a larger scale, and this method resulted in a more rapid production of high-grade spruce.⁴ In logging selectively an area was combed of all trees which were of airplane quality, and the others were left standing. This method avoided the cutting of low-grade spruce and other timber for which there was no market.

The cost of logging Sitka spruce has varied widely, more particularly during and since the war. Before the war the average cost of logging was about \$5.50 per thousand feet; in 1919 it amounted to approximately \$11 per thousand feet; and in 1920 it was somewhat higher.

Sitka spruce timber is normally cut into logs ranging from 32 to 40 feet in length. As about 40 per cent of all timber cut on the Pacific coastal region is logged by operators engaged solely in logging, who sell their logs in the open market, logs are graded according to size and quality into No. 1, 2, and 3 logs. It is estimated that Sitka spruce timber as logged will grade: Twenty per cent No. 1 logs, 40 per cent No. 2, and 40 per cent No. 3. Prior to the war Sitka spruce logs sold for about \$12, \$9, and \$6 per thousand for No. 1, 2, and 3 logs, respectively. In 1920 they sold for \$30, \$24, and \$18 on this basis. At the height of war-time operations in 1918 a price of \$35 for No. 1 logs was reached.

Most of the Sitka spruce lumber that is manufactured in the United States is cut in the large band sawmills of the Coos Bay district of Oregon and the Grays Harbor and Willapa Bay districts of Washington. The sawmills of Alaska, with a daily capacity of 25,000 to 40,000 board feet of lumber, are smaller comparatively.

The cost of manufacture before the war was a little less than \$5.50 per thousand feet; in 1919 it amounted to about \$12, and in 1920 it was a little higher.

Although exceedingly high prices were paid in 1918 for clear lumber suitable for aircraft construction, the average wholesale value of mill-run Sitka spruce in that year varied from \$20 to \$27 per thousand board feet. (See table 2.) Before the war an average price of about \$14 obtained. Prices on January 1, 1919, are given in table 3.

⁴ "History of Spruce Production Division," 1919.

TABLE 3.—*Range in selling prices of different grades of spruce lumber (f. o. b. mill), January 1, 1919.*

Grade.	Price per 1,000 ft. b. m.
"B" and better, finish, S2S	\$35.00 to \$62.00
Factory select and better, S2S	35.00 to 62.00
No. 1 shop, S2S	32.00 to 39.00
Shop common, S2S	30.00
No. 2 shop, S2S	27.00 to 34.00
Box, Nos. 1, 2, and 3, S2S	26.00 to 28.00
Common boards, S2S	25.00
Common dimension, S1S1E	17.50 to 30.00

Regarding the prices of Sitka spruce stumpage, it may be said that they varied as greatly in the last few years as did logging and milling costs. Ten years ago average stumpage was worth about \$1.50 per thousand feet. Just prior to our entrance into the war it was about \$2.75 per thousand feet, and in 1920 it reached \$3.50. During 1918 stumpage values of selected trees to be cut in riving or logging operations ran as high as \$7.50 per thousand feet. Sitka spruce stumpage, of course, like that of other species, varies in value with topography and accessibility. For this reason values greater than those given here, as well as values considerably less, have obtained.

SIZE, AGE, AND DISTINGUISHING CHARACTERISTICS.

SIZE.

Sitka spruce, which is the largest of the spruces, grows to a size comparable with the maximum for Douglas fir and cedar, and larger than its other associates.

When maximum sizes are considered, individual specimens of Sitka spruce have been found to attain surprisingly large proportions. Total heights of 296, 285, and 282 feet were recorded in the course of the field work for this study for individuals found in the vicinity of Quinault Lake and Beaver, Wash. All these trees were under 300 years of age. Specimens which measured over 9 feet in diameter at a height of 10 feet above ground were found not merely once or twice, but many times, in both Oregon and Washington forests. The largest diameter recorded was of a tree which grew near Beaver, Wash. It measured 16 feet in diameter at breast height, and because of its gradual basal taper was of large volume (Pl. VI, figs. 1 and 2). Necessarily, large diameters and heights mean large volume, and individual trees in Oregon and Washington occasionally have scaled 40,000 board feet in merchantable contents; but the average tree scales about 8,000 board feet. In Alaska single trees have scaled 24,000 board feet of merchantable material.⁵

⁵ "Production of Airplane Lumber in Alaska," by W. G. Weigle, *Alaska Pioneer*, vol. 1, No. 2, p. 4, 1918.

The species attains its maximum development in Washington and Oregon. The average tree found in the virgin forest has a height of about 230 feet and a diameter of 4 feet, measured 15 feet above ground. North of the optimum range in British Columbia it grows to maximum diameters of 8 to 12 feet and heights of 160 to 180 feet; but ordinarily it is only 3 to 6 feet in diameter.⁶ In Alaska, too, its average diameter is 3 feet and its height about 150 feet, but single trees frequently exceed this. In California it is smaller than farther north and becomes only a medium-sized tree. This subject is discussed more fully under the heading "Growth."

LONGEVITY.

Sitka spruce is a long-lived tree. Sudworth reports a maximum age of 750 years.⁷ During the recent study, however, the oldest tree that could be found was 586 years of age. It is doubtful whether many individuals ever reach an age of over 600 years, and the mean mature age is not more than 450 years.

DISTINGUISHING CHARACTERISTICS.

An outstanding characteristic of the appearance in the forest of Sitka spruce is its bark (Pl. VII). The thin, stiff, cupped, and elliptical dark purple-gray scales 1 or 2 inches in diameter make this species easily distinguishable from its associates in the stand. Little protection is afforded to the living tissues, however, by the bark, which is only one-half to 1 inch thick.

The needles are also of distinctive appearance. In spring the yellowish green color of new needles in sprays that bend downward limply at the ends of the branches stands out in contrast with the dark bluish green of the older needles; and although the young leaves are soft and velvety to the touch, during the remainder of their 5 to 6 year existence they are stiff and stand out straight in all directions around the twig, each needle tip being keenly pointed and quite bristly to the touch. The leaves are somewhat flattened, only indistinctly four-angled, and about 1 inch long.

The cones, too, exhibit peculiarities by which this species may be identified. They have an average length of 3 inches, are light brown in color, elliptical in shape, and hang down conspicuously from the upper branches. The cone scales are thin and papery, with irregular margins but slightly pointed in general outline, and are firmly attached to the central stalk of the cone. Maturity is reached at the end of one year's development; soon thereafter the scales open and release the small dark brown seeds with their large thin wings adhering to them. Most of the cones drop from the

⁶ "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 199, 1918.

⁷ "Forest Trees of the Pacific Slope," G. B. Sudworth, p. 83, 1908.

tree soon after the seeds have been scattered by the wind, but some cones may remain on the branches for a number of years.

The root system is characteristically shallow. This is especially true of trees on swampy soils where the roots spread out very close to the surface; but on deep, porous soils they penetrate 4 to 5 feet into the ground and occasionally as far as 12 feet.

Characteristics of form are unimportant, with one exception, for the recognition of this species. In general, the forest-grown trees are tall, with open, conical crowns and long, cylindrical boles. Their bases are very commonly heavily buttressed. Plates VI (fig. 3), VIII, and IX show the importance of this fact when form is considered. Plate IX, figure 2, gives one clue to its cause; the stumps illustrated in this plate were those of only two out of seven fully grown trees that developed on this one windfall. Basal or butt swell is common in this species and especially so in trees which occur on the lowlands. Incidentally, it should be mentioned that this condition in the tree very materially affects any diameter measurements, for the standard practice in all species is to measure diameters at a uniform height of $4\frac{1}{2}$ feet above the ground, and this practice would give very inconsistent results with large Sitka spruces. Further discussion of this point appears under "Diameter growth." The overmature trees present another characteristic, that of stag-headedness. (Pl. VI, fig. 2.) Such broken-topped trees are apt to develop ascending side branches, and these may grow to 14 inches and more in diameter and 50 feet in height. Trees in this condition, as shown by the cedar snags in Plate XIV, may be called bayonet-topped.

OCCURRENCE.

Sitka spruce stands are found on a variety of sites but may be grouped broadly into two classes—the bottomland or lowland, and the slope or highland. The development of the tree, which to a great extent is influenced by the amount of soil moisture, is the chief difference between the two types, and the altitudinal situation is of only minor consideration. The forest may be of pure spruce or of spruce in mixture with other species. These types occur throughout the range of the species, and a third or "upper slope" type might be added for Alaska to include the bodies of scrubby spruce near the upper altitudinal limit of tree growth.

BOTTOMLAND TYPE.

This type is found in the moist situations of river bottoms and benches above the river beds where there is a deep, rich alluvial soil, and where in places the heavy precipitation of the winter and spring months has so saturated the ground that standing water is not un-

common. Here the trees, though large and tall, are characterized by large buttressed bases, limbiness, and comparatively short clear length. On these moist sites the trees make a noticeably rapid and well-sustained diameter growth, especially from 100 to 200 years of age. In this type Sitka spruce occurs also on tidelands and in swamps where there is considerable inundation; but, although it can stand these conditions, it prefers an excess of soil moisture only with good drainage and in general avoids stagnant sites and acid soils. In contrast with the stands on the bottoms and benches, those in swamps are quite frequently pure, but the trees here are shorter and much more limby. Trees which occur on exposed situations along the coast are small and scrubby and unfit for commercial uses.

SLOPE TYPE.

Spruce stands of the slope type are found on the moist but well-drained hills which border the lowlands and which afford all advantages for excellent growth in their rounded ridges and gentle slopes of deep, rich soil. It is not only in the upland country that this type occurs; similar conditions exist on the rolling, sandy land along the coast. The trees on such sites are fine specimens, large and tall, with long, clear length; and, in contrast with those of the bottomland type they seldom develop buttressed bases. (Pl. XI.) The wood is characteristically fine-grained, and this fact is frequently mentioned by lumbermen as a means of distinguishing between trees of the two types. Spruce in these stands is more often pure than in mixture, and this is especially true on the sandy lands which border the ocean. (Pl. XII.)

COMPOSITION AND VOLUME OF STAND.

Pure stands of Sitka spruce are usually not extensive but are apt to be limited to patches of a few acres in contrast with Douglas fir, which occurs pure over great areas. Larger pure forests of spruce are found occasionally, however, 40 or more acres in size in Oregon, Washington, and British Columbia, and even 100 acres in Alaska; but this is the exception rather than the rule.

When Sitka spruce grows in mixture with other species, the most common associate is western hemlock, and large areas of these two species are found in Alaska and in the States as well. Sitka spruce is also associated with Douglas fir, western red cedar, lowland white fir, silver fir, and Pacific yew throughout the range, with Port Orford cedar and redwood only in southern Oregon and California, and with Alaska cedar and mountain hemlock on the upper slopes in British Columbia and Alaska. In the valley bottoms it occurs with such hardwoods as broadleaf maple, black cottonwood, and red alder. (Pl. X.)

The composition of a typical piece of what is distinguished as the "western hemlock-Sitka spruce type" in British Columbia is as follows:⁸

	Per cent.
Western hemlock	38
Sitka spruce	27
Western red cedar	15
Balsam (silver) fir	15
Others (Alaska cedar and cottonwood)	5
	100

A summary of cruises made in 1918 in spruce stands on the west side of the Olympic National Forest in Washington shows the following average composition of the forest:⁹

	Per cent.
Western hemlock	37
Douglas fir	26
Sitka spruce	21
Silver fir	7
Western red cedar	6
Others	3
	100

The mixed forest is usually of even age; infrequently it is of two age classes, and then the hemlock trees are the smaller and younger ones of the stand. An all-aged forest occurs but rarely, and then as an open stand on swampy soils.

An idea of the composition of the stand and the representation of small-sized trees of other species (in the older stands) may be gained from Table 4. This table shows the results of measurements on 12 sample plots in typical stands in Oregon and Washington in which Sitka spruce comprised from 50 to 100 per cent of the volume of the stand.

TABLE 4.—*Number of trees of Sitka spruce and other species per acre for typical stands of various ages.*

Plots.			Living trees per acre.				
Designation and locality.	Area.	Age.	Sitka spruce.		Other species.		Total.
			Under 12 inches.	Over 12 inches.	Under 12 inches.	Over 12 inches.	
	<i>Acres.</i>	<i>Years.</i>					
Newport III.....	0.4	27	448.0	122.0	30.0	0.0	600.0
Blodgett I.....	.2	60	104.0	112.0	24.0	32.0	272.0
Raymond I.....	4.0	70	1.5	27.7	25.2	98.0	152.4
Newport I.....	2.0	130	2.5	61.0	3.0	8.0	74.5
Tsiltcoos II.....	2.0	175	1.5	49.5	10.0	13.5	74.5
Raymond II.....	4.0	175	3.5	13.2	13.8	41.2	71.7
Hoquiam I.....	4.0	240	.0	18.0	28.2	18.8	65.0
Beaver I.....	4.0	260	.2	18.2	5.3	9.6	33.3
Tsiltcoos I.....	4.0	290	.5	21.5	8.0	8.0	38.0
Clatsop I.....	5.2	310	.0	10.1	.0	10.3	20.4
Newport II.....	2.0	320	3.0	7.0	43.5	54.0	107.5
Hoquiam II.....	2.0	340	.0	7.0	40.0	34.0	81.0

⁸ "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 61, 1918.

⁹ "Descriptive Report of Olympic West Side Spruce," by C. J. Conover. Forest Service manuscript report, p. 13, 1918.

The underbrush, which in both the pure and mixed forests is extremely large and dense, is composed of salmonberry, huckleberry, vine maple, salal, devil's club, elderberry, and cascara, with a preponderance of the first two species. The ground cover consists chiefly of braken, sword ferns, and moss.

The volume of spruce per acre in the virgin stand varies greatly with the proportion of species, the density of stocking, and the quality of the site. The heaviest yields are naturally produced in properly stocked stands on sites where the best growth of individual trees is made. County cruise estimates indicate that the stand of merchantable timber in what would be classed as spruce type (running all the way from 25 per cent to 65 per cent of spruce) varies from 20,000 to 100,000 feet per acre over large areas. Very much heavier, as well as lighter, stands occur in the virgin woods.

CLIMATIC AND SOIL REQUIREMENTS.

Sitka spruce is very exacting in its soil and atmospheric moisture requirements. An abundance of rainfall, frequent fogs, and temperatures moderated by proximity to the sea are the climatic characteristics of the north Pacific coastal strip where this species grows. The yearly precipitation is 75 to 150 inches or more and comes chiefly in the form of rain, well distributed throughout the year, except for about two months in midsummer. Cloudy or partly cloudy days are frequent, and weather records show an average of 240 such days in a single year at one station in the heart of the spruce region. The temperature of the region is generally mild, the annual mean ranging from 38° F. in Alaska to 53° in northern California. Extreme temperatures of 15° below zero in Alaska and 102° above in California are encountered within the range of the tree; but withal it may very readily be seen that Sitka spruce occurs only on areas that offer climatic advantages favorable for growth.

Its soil requirements, however, are not so distinctly defined, and thin, rocky soils on the slopes, pure sand along the coast, and deep, rich alluvial deposits of rivers share equally, under similar conditions of climate, in the distribution of the species; but the trees are larger and reach better development on bottom lands of moist, friable, sandy loam. It is noteworthy that in Alaska the heaviest stands of spruce and those of best quality are found on limestone soils, perhaps partly because these are the deepest and most completely decomposed. Though this species demands a very great amount of soil moisture and can grow on swampy sites, it attains its best development on soils of good drainage.

LIGHT REQUIREMENTS.

Sitka spruce, unlike other spruce, is somewhat intolerant of shade. Compared with its associates, it is less tolerant than western hemlock and western red cedar and about as tolerant as Douglas fir. Seedlings can endure heavy shade and on old burns and logged-over areas establish themselves with little difficulty under the dense cover of deciduous brush, such as salmonberry and huckleberry, and of other coniferous seedling growth; but strangely enough Sitka spruce is seldom found under the heavy canopy of a mature stand. Here temperature, not tolerance, is thought to be the governing factor, and the coolness in the mature stands prevents, whereas the warmth in the openings permits, the germination and establishment of spruce seedlings. As the tree advances in age it demands overhead light, and dies if long overtopped.

The dead side branches, which are often moss-covered stubs 2 or 3 feet long and characteristically coarse and stiff, are very persistent in young spruce. The shedding of the dead limbs and cleaning of the bole starts when the trees are about 50 years old and often is not completed for a century or more. (Pl. XII and Pl. XIII (fig. 1.))

REPRODUCTION.

SEED PRODUCTION AND DISSEMINATION.

Sitka spruce is a prolific seeder. Open-grown trees commence to bear seed at 35 years of age, and trees of all sites are vigorous producers of seed until maturity. Some seed is produced each year and heavy crops are yielded every three or four years. The cones mature in the early fall of the first year and, under normal conditions, open and release the seed within a short period afterwards. A mature tree with a full crown may produce, in a good seed year, 4 to 6 bushels of cones, which yield from 0.65¹⁰ to 1.25¹¹ pounds of clean seed. A pound of these seeds will number between 200,000 and 300,000. Because of their small size and relatively large wings they are often carried by the wind 400 feet or more from the base of the tree. Many of the seeds filter into the deep duff of the forest floor and are stored, their hard covering keeping them viable for several years. The seed has a high percentage of germination. In tests¹² of fresh commercial seed under greenhouse conditions, this amounts to 72 per cent, and is higher than the germination percentage of western hemlock, western red cedar, and Douglas fir as determined in similar tests.

¹⁰ "Sitka Spruce in Alaska," by B. E. Hoffman. Forest Service manuscript report, p. 9, 1912.

¹¹ "Reforestation on the National Forests," by C. R. Tillotson. U. S. Dept. Agr. Bull. 475, p. 17, 1917.

¹² "Seeding and Planting," by J. W. Toumey, p. 122, 1916.



F-150849

FIG. 1.—VARIATION IN BASAL SWELL, ILLUSTRATED BY TREES IN LEFT AND RIGHT FOREGROUND.



F-150850

FIG. 2. STUMPS OF MATURE TREES WHICH STARTED ON OLD WINDFALL.



F—NLC-9

SITKA SPRUCE IN MIXTURE WITH RED ALDER AND BROADLEAF MAPLE ON RIVER BOTTOM.



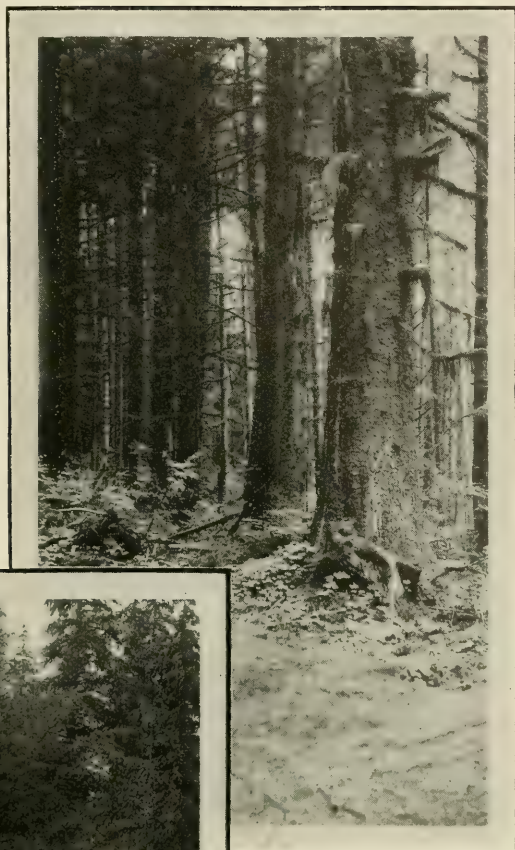
F. N. C. 10

HIGHLAND SPRUCE AT 1,100 FEET ELEVATION IN CLATSOP COUNTY, OREG.



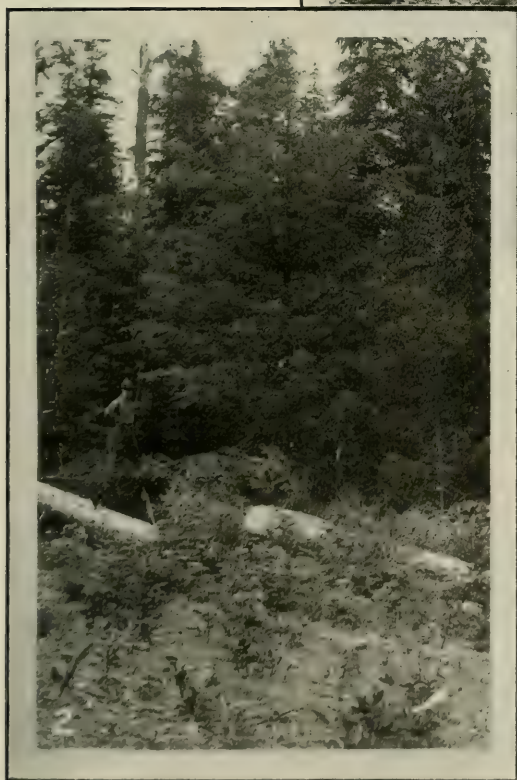
F—150834

PURE, EVEN-AGED STAND OF SITKA SPRUCE (175 YEARS) NEAR TSILTCOOS LAKE, OREG.



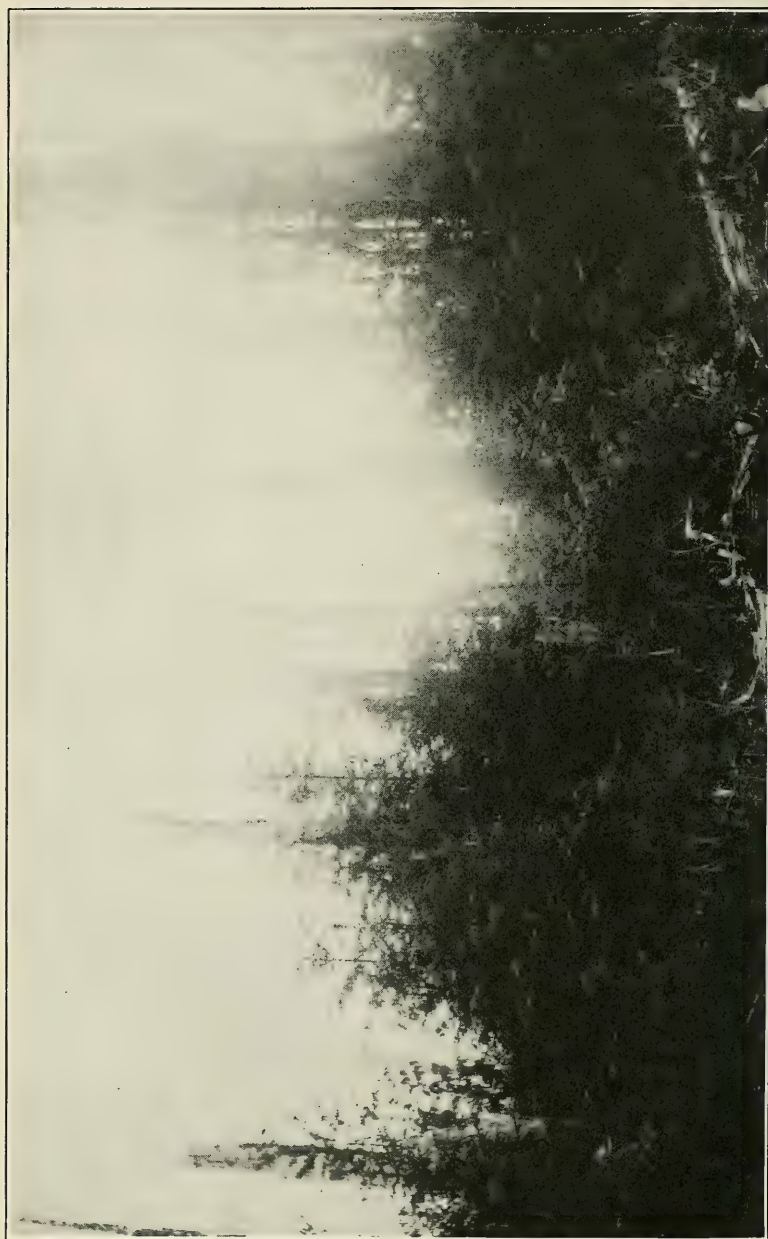
F—NLC-11

FIG. 1.—A STAND OF 65-YEAR-OLD SPRUCE WITH UNCLEARED BOLES.



F—NLC-12

FIG. 2. THRIFTY 18-YEAR-OLD SITKA SPRUCE IN OLD CLEARING.



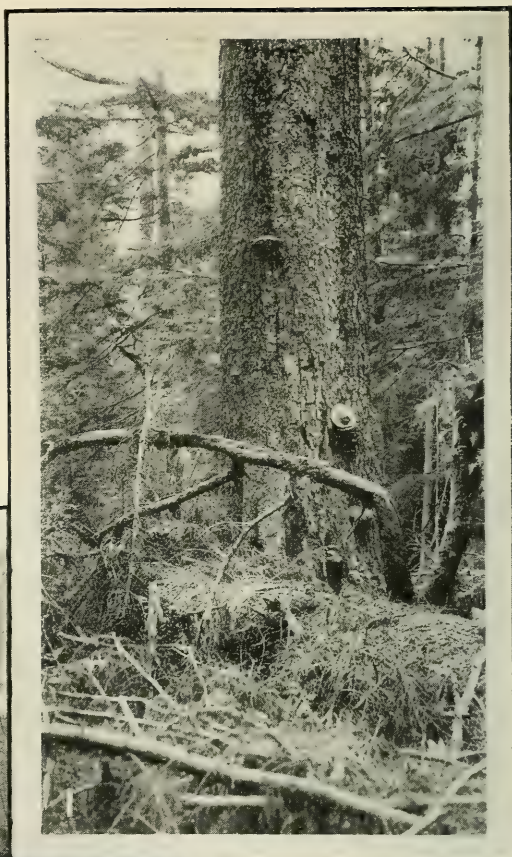
F-NIC-13

DENSE REPRODUCTION OF SITKA SPRUCE, CEDAR, AND HEMLOCK ON QUINULT BURN IN WASHINGTON.



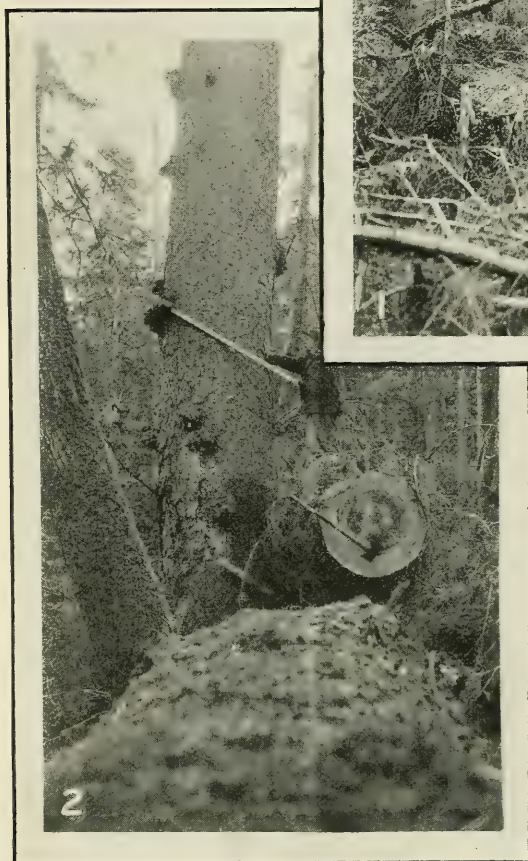
F-110-14

FULLY STOCKED SECOND-GROWTH STAND OF 27-YEAR-OLD SITKA SPRUCE.



F—NLC-15

FIG. 1.—FRUITING BODIES
OF *FOMES PINICOLA*.



F—NLC-16

FIG. 2.—FRUITING BODIES OF *TRAMETES PINI*.

ESTABLISHMENT OF SEEDLINGS.

Sitka spruce germinates slowly, and in this habit it is similar to other low-altitude species of the coastal region, and in contrast with Engelmann spruce and high-altitude Douglas fir, which require only a short time for germination. Similarly, Sitka spruce seedlings do not respond quickly to atmospheric warmth early in the spring, and their buds do not unfold until the season is well advanced. Were it not for this characteristic much injury to reproduction would result, for during early spring clear, warm weather in the lowlands is often followed by killing frosts.

Moisture, light, and heat are all essential for the germination and establishment of spruce seedlings; but, as moisture is abundantly supplied by rains and fogs in the region, and as the young seedlings are capable of enduring dense shade, heat is the uncertain factor. In this regard the warm exposures of old burns, clearings, and logged-over lands offer conditions more suitable for growth than elsewhere, and, as spruce can compete successfully with all other species, it establishes itself with little difficulty on these sites. In the choice of seed bed, Sitka spruce prefers loose mineral soil, but it can thrive equally well in the decayed wood of down logs and in the deep humus of the forest floor. Plate IX, figure 2, illustrates the establishment of two spruce trees on an old windfall. Because of its extreme tolerance in early youth, Sitka spruce sometimes occurs on fresh earth slides, under a temporary cover type of alder, and eventually becomes the predominating species.

Stands of reproduction in the spruce type are densely stocked. (Pls. XIV and XV.) Counts were made during the recent field study on 10 square-rod quadrates in areas of reproduction, and these counts showed that in thrifty stands under 10 years old there were 3,000 seedlings per acre, and that in stands 30 years old there were 500 trees per acre. Nearly one-quarter of the 30-year-old trees were 12 inches and over in diameter at breastheight. It was also shown that a stand of maximum density, which was 5 years old, contained 35,000 seedlings per acre. In each of these stands 50 per cent or more was spruce, and the remainder was mostly hemlock, with a few cedar and Douglas fir trees. In very dense stands Sitka spruce seedlings generally comprise only 10 to 20 per cent, but this percentage often increases as the stands become older. Under ordinary circumstances spruce is able to maintain itself and even increase notwithstanding the competition of other species. These seedlings, which are rather delicate and slender stemmed during the first few years, later develop heavy, stiff stems. They at first average nearly one-half foot in height growth per year and beyond 15 years of age increase in height at the rate of 3 feet per year.

CAUSES OF INJURY.

FUNGI.¹³

Sitka spruce, in common with other forest trees, is attacked by two broad groups of fungi—first, those reducing the annual increment; and, second, those reducing the merchantable timber.

In the first group there are two rust fungi. One of these is a broom-forming rust (*Peridermium coloradense*). The mycelium of the fungus is perennial in the twigs of the host, causing pronounced witches' brooms. As a rule, this fungus is not serious, but it may completely dwarf and deform small trees.

The other rust fungus (*Peridermium decolorans*) does not cause any deformation of the host. The mycelium confines itself to the infected needles and does not enter the twigs or branches. The parasite is usually confined to small trees of the sapling and small-pole sizes.

Another needle disease of importance is characterized by a browning of the individual needles. This fungus is *Lophodermium macrosporum* or a closely related species. Infected needles are invariably killed and drop off, but the degree of infection varies. Sometimes only occasional needles are diseased; at other times most of them may be killed. The disease usually attacks the lower branches of young trees. It has been reported as very prevalent along the lower Columbia River in Clatsop County, Oreg.

It is impossible to give an estimate of the amount of damage caused by the needle and twig diseases just mentioned. It is obvious that there must be a greater or less reduction in annual increment of the infected trees, but no exact data are available. Control measures need not be discussed, as present economic conditions preclude such work, except for nursery stock or trees of high aesthetic value.

By far the most important fungi are those which reduce the merchantable volume by attacking and destroying the heartwood of living trees.

The most serious of these on Sitka spruce is the ring-scale fungus (*Trametes pini*) which causes the common red rot or conk rot in the heartwood of living trees. In spruce the attack may be made at any point along the bole. In the split section the decayed wood has a reddish color in its early stages, and later small white sunken spots are found separated by apparently sound reddish wood. The fungus gains entrance to the heartwood of the trees principally through old branch stubs and is exceedingly destructive in mature and over-mature stands. Plates XVI (fig. 2) and XVII are illustrations of this fungus.

Next in importance is the velvet-top fungus (*Polyporus schweinitzii*), which causes a pronounced butt rot. The sporophores ap-

¹³ Prepared in collaboration with Dr. J. S. Boyce, Pathologist, Bureau of Plant Industry.

pear at the base of the tree, on the trunk in old wounds, or on the ground, coming up from decayed roots. Those on the ground have a short, thick stalk. The disease spreads both by spores blown about in the air and through the ground by means of the decayed roots. The decay which is confined to the heartwood is light reddish brown in the early stages, and pronouncedly cubical, reddish brown, crumbling to a fine powder between the fingers, and often with thin resinous crusts of mycelium in the typical stage. The rot is found in the roots and butt, and rarely extends beyond the first log. Besides the actual loss due to the volume of wood rendered unmerchantable by decay, the infected tree is frequently broken off at the base as a result of the weakening of the roots. Many large overmature trees, completely rotted at the base except for a thin layer of sapwood, are found broken off between 5 and 20 feet above ground, and their loss can be charged directly to the destructive work of this fungus.

The red-belt fungus (*Fomes pinicola*) is of equal importance with *Polyporus schweinitzii* as a butt rot in living trees; but it is also common on dead snags, old windfalls, stumps, and other débris, and thus functions as a beneficial scavenger in the forest. The fruiting bodies are usually found at the base of the tree in the flare of the roots or at scars along the lower portion of the trunk. The typical decay is light reddish-brown in color, somewhat cubical, crumbly and brittle, with white feltlike layers of mycelium occupying the cracks. Infection caused by this fungus is illustrated in Plate XVI, figure 1.

One of the most common fungi found on fallen Sitka spruce, besides the red-belt fungus, is the lacquer-top fungus* (*Ganoderma oregonense*), readily recognized by the shiny, lacquerlike, reddish upper surface of the annual fruiting body. This organism has not been reported on a living spruce, but is often found on its associate, the hemlock. There are a number of other fungi of less importance which live on fallen trunks, but do not attack living trees.

Sitka spruce is much freer from decay than either western hemlock or Douglas fir, but snags and down timber decay very rapidly. The earliest infection appears in trees between 60 and 100 years of age; only a slight amount of rot is found in stands between 150 and 300 years of age, and this is confined to the butts of trees. Over 300 years, or after maturity, however, the tops commonly break off, and top rot as well as butt rot is very prevalent, becoming more marked with age. It is not unusual, however, to find trees of 400 years entirely sound at the butt and with very little decay along the trunk or in the top. In general, this species is remarkably free from decay up to 200 years of age.

The amount of resin which the wood of a tree contains, or that it is able to produce to cover any injury, affects its ability to ward off disease. Spruce, which has very little resin, is almost never able

to heal over scars or wounds along the bole; here the spores of fungi soon establish themselves and, on account of the very moist conditions in spruce stands, cause the rapid decay of much sound wood.

Advance rot spreads quickly in this species, and, though often hard to detect, it becomes very noticeable after lumber is dried. It is commonly, though not always, accompanied by a change of color in the wood, appearing as streaks of red, yellow, or green. Tests were made recently by pathologists to show the effect of different stages of decay on the strength of the wood, particularly for spruce airplane stock, but these data are not yet available for publication.

INSECTS.¹⁴

Although Sitka spruce, like other forest trees, is subject to insect attacks, it is not so susceptible as most of its associates in the forests of the Pacific coastal region. The attacks are naturally more serious in pure or nearly pure stands of Sitka spruce than in stands in which it occurs in mixture. Damage is caused by three classes of insects—bark beetles, defoliators, and borers. The first two classes attack standing timber and the last works in felled trees.

The most important insect enemies of Sitka spruce are the bark beetles, of which the most destructive is the Sitka spruce beetle (*Dendroctonus obesus*). This beetle attacks the living trees and kills them by girdling in the cambium layer. In attacking the trees the first broods enter the inner bark of the middle trunk, and those which appear later extend the infestation to the base of the trunk and even to the larger roots. This beetle also works in the inner bark of stumps, logs, and slash of felled trees. Although no extensive depredations of the Sitka spruce beetle have been found thus far, it has been reported now and then that groups of Sitka spruce have been killed by its activity. If infestations should ever become widespread it would be possible to practice control operations by cutting and barking the infested trees before the beetles emerge in the late spring. It would not be necessary to burn the bark in this work.¹⁵

From time to time Sitka spruce is subject to the attacks of such defoliators as caterpillars, sawfly larvæ, and aphids, all of which destroy the needles and may therefore occasionally kill trees over large areas. In Clatsop County, Oreg., in 1890 and 1891, Sitka spruce and western hemlock were attacked and killed over an area of thousands of acres by a caterpillar belonging to the Geometrid family. During the years 1917 to 1920 the Sitka spruce and western hemlock on several hundred thousand acres on the Tongass National

¹⁴ Prepared in collaboration with Forest Examiner A. J. Jaenicke, U. S. Forest Service.

¹⁵ For detailed information regarding control measures, see Bulletin 83, Part I, "Bark Beetles of the Genus *Dendroctonus*," by A. D. Hopkins, Bureau of Entomology, U. S. Department of Agriculture.

Forest in southeastern Alaska were defoliated by the combined activity of sawfly larvæ and caterpillars belonging to the Tineid family. Thus far only a small portion of the Sitka spruce in southeastern Alaska has been killed by this widespread defoliation.

Occasionally aphids kill the foliage of Sitka spruce. The western spruce gall louse (*Aphis abietina*) is believed by Dr. A. D. Hopkins of the Bureau of Entomology to be the aphid which caused the loss of the needles of Sitka spruce over thousands of acres of forest in 1918 in various portions of the coast region in Oregon and Washington. Fortunately the activity of this aphid was of extremely short duration, and only about 15 per cent of the infested spruce was killed. Most of this loss was confined to swamp and tideland areas in the lower Columbia River basin and the coast region and included only the poorer stands of timber. The Sitka spruce gall aphid (*Chermes cooleyi*) is found very commonly doing injury to Sitka spruce reproduction and occasionally causing its death. Large trees also are attacked, but the injury to them is rarely severe. These minute insects cause the development of conelike galls which kill the affected twigs. Infested trees of special value, such as those in parks and streets, may often, with good results, be sprayed with contact sprays like kerosene emulsion.

Fortunately the work of defoliators does not continue more than a few years when it is controlled by natural agencies. Under forest conditions control measures against this class of insects are not feasible. However, defoliators greatly increase the fire hazard on the areas on which they have been active. Nearly always the fires which followed the defoliators did more damage than the insects themselves. The reduction of the fire risk on the defoliated areas is, therefore, an important consideration in defoliator problems.

Felled timber of Sitka spruce is subject to the attacks of various wood borers. Logs cut between April and September are frequently attacked, shortly after being felled, by ambrosia beetles, sometimes called timber beetles or pinhole borers. These are small, elongate, wood-boring beetles which excavate round black tunnels, the diameter of a pencil lead, into the wood of dying trees and stumps, as well as logs. Investigations by the Bureau of Entomology in 1919 showed that species of *Gnathothrichus* and *Xyloterus* commonly attack Sitka spruce logs, as well as western hemlock and Douglas fir. These borers may penetrate the wood to a depth of from 4 to 6 inches and therefore seriously reduce the value of the sapwood, especially when Sitka spruce is being used for such special purposes as airplane stock. The logs which are cut in the late fall and winter are usually attacked in the following spring. Logs cut in the early fall are not entered that season; and, if piled loosely in

the open, they often dry sufficiently to be protected from attack the following spring. Logs placed in water are safe from further injury. Damage by these borers can be prevented almost entirely by removing the logs from the woods or placing them in water as soon as they are cut.

Larger wood borers are an important factor in the deterioration of the sapwood and heartwood of fire-killed trees and logs. During the first two summers after the death of the trees or the felling of the trees the borers are most active, and at the end of the two-year period the salvage value is usually next to nothing. If the logs are placed in water or barked within a few weeks after cutting, losses by these borers may be avoided. Logs which are loosely piled in the open soon after cutting usually escape damage because of the rapid drying out of the thin bark, which is then unattractive to the borers for the laying of eggs. Dr. J. M. Swaine, of the Canadian Entomological Branch, recommends covering the logs thickly with brush. The logs to be covered should be piled on skidways and given a very thick covering of green limbs so that the sunlight can not penetrate at all to the logs beneath.

WIND.

Sitka spruce, because of its characteristically shallow root system, can not withstand severe winds. Trees which grow on exposed situations along the coast where they encounter severe winds are windfirm, but they are also scrubby and of little use for lumber. In the virgin forests under normal conditions only the very diseased trees are likely to be windthrown, but in cut-over areas trees isolated by logging and those which border on fresh cuttings are invariably windthrown. (Pl. XVIII.) Spruce trees which have grown in dense stands never become wind-resistant, and full consideration must be given this fact before a method of cutting and a management policy are adopted for a spruce forest.

The hurricane that swept the western edge of the Olympic peninsula, Washington, in January, 1921, felled from 5 to 95 per cent of the timber on a swath 60 miles long and 20 miles wide in the heart of the spruce belt. Six billion feet or more of virgin western hemlock, Sitka spruce, Douglas fir, silver fir, and western red cedar timber was laid flat by the wind. Perhaps a billion feet of Sitka spruce in the State of Washington was windthrown in that storm. All species suffered alike regardless of their relative windfirmness.

In addition to windthrow, other damage from the elements is wrought upon spruce timber by breakage and wind-shake. The breakage consists in the shattering of the tops of overmature and decadent trees, and this permits the entrance of fungous growth,

which spreads quickly through the sound wood and renders much of the upper trunk unmerchantable. Damage from this cause is very common in trees over 300 years of age. Wind-shake is a mechanical defect resulting from heavy stresses in the butt section which are caused by the action of severe winds, and is of infrequent occurrence in large trees. This circular or radial rupture of the wood considerably reduces the value of the tree for lumber.

BURLS.

Another injury is the formation of huge burls along the trunks. This defect has been found abundantly in a limited area in Oregon. The illustrations in Plate XIX are typical examples of the defect. Its cause is uncertain, though probably analogous to similar malformations in many other species.

FIRE.

Sitka spruce is fortunate in having as its habitat a region in which there is less forest-fire hazard than in most parts of the coniferous forest regions of western North America. Frequent rains throughout the year in southeastern Alaska make fires in the virgin spruce woods there quite uncommon; farther south in Washington and Oregon there is more danger of forest fires in the short dry season. Fires in this region are apt to run in the crowns of the trees, and they do so even in the spring months when the surface litter is still too wet to burn. The moss that hangs on the branches of the hemlock, spruce, and fir trees is very inflammable and helps to carry fire. The spruce region of Oregon suffered from several very disastrous and widespread fires a few decades ago, as the "burns" of the Coast Range witness.

Sitka spruce is very susceptible to fire. This is due chiefly to its thin bark, which at stump height is only a half-inch to an inch thick. Fire-scars are uncommon in Sitka spruce, for even a very light surface fire is sufficient to kill the cambium, and the trees, thus girdled, die.

Although an individual tree of Sitka spruce is more susceptible to injury than a Douglas fir of the same size, the forest in which it grows along the coast is less subject to fire than the forest farther inland where Douglas fir predominates. Even though the danger of uncontrollable fires is less in the Coast Range than in the Cascade Range, careful fire protection in both regions is imperative.

GROWTH.

Sitka spruce is one of the most rapid-growing coniferous species in the Pacific Northwest. In keeping with the character of spruces in general, its growth during the first few years is less than that of

many other conifers; but thereafter it increases in size with great rapidity and maintains a fast growth until late in life. Its rate of growth naturally varies with the quality and the character of stand. Moisture conditions are an important factor and growth is more rapid on wet bottomland situations than on the drier slopes. The growth of Sitka spruce varies also in different parts of its range, and is more rapid in Oregon, Washington, and British Columbia than either farther south or north. Average figures on height, diameter, and volume growth are given in the tables that follow, but it is realized that these are not universally applicable. In the appendix will be found tables of growth from several different localities.

HEIGHT.

In the seedling stage the height growth of Sitka spruce is fairly rapid, but not so fast at this period as that of its associates, Douglas fir, western hemlock, and western red cedar. Table 5 shows the height growth of dominant, open-grown Sitka spruce seedlings, and is compiled from measurements taken of young trees which grew in seven different localities and sites in Oregon and Washington. Here the reproduction was sometimes found in pure stands, but more often in mixture with other species.

TABLE 5.—*Height of dominant, open-grown Sitka spruce seedlings, averaged for all sites in Oregon and Washington.*

[Based on 2,102 sectional measurements of 322 trees.]

(Curved.)

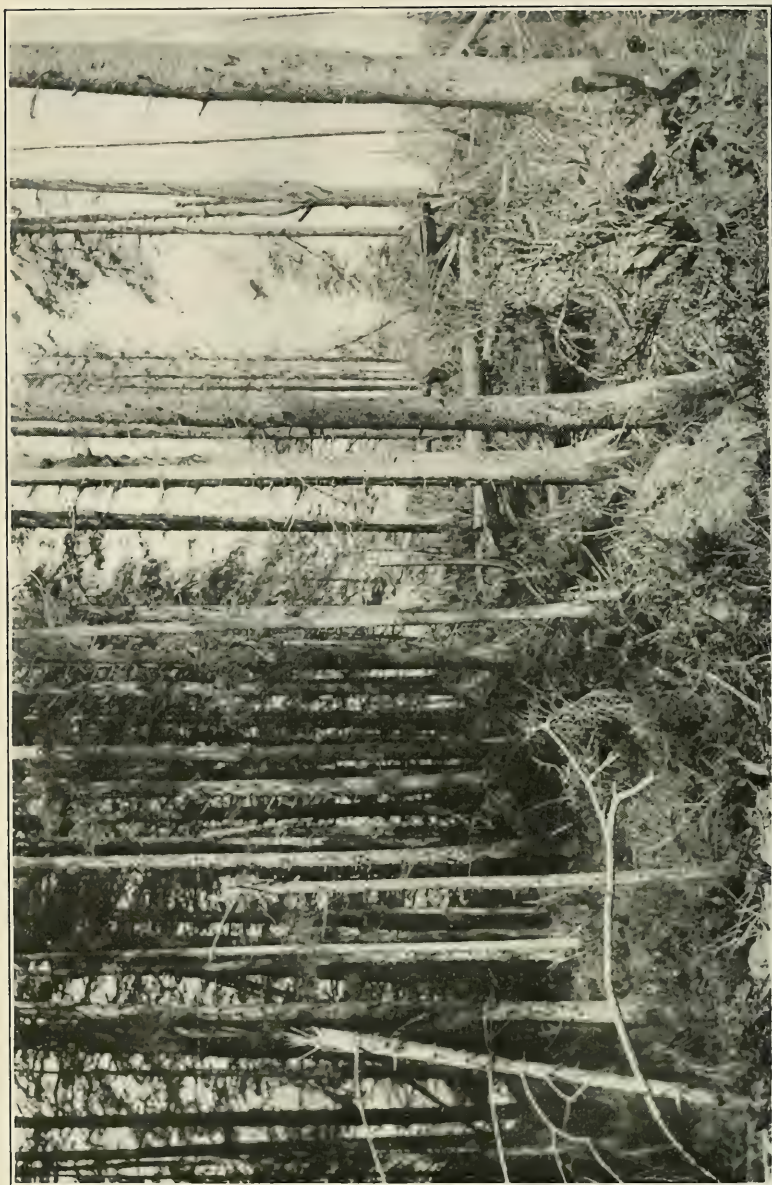
Age.	Height.	Current annual growth.	Age.	Height.	Current annual growth.
<i>Years.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Years.</i>	<i>Feet.</i>	<i>Feet.</i>
1.....	0.2	0.2	10.....	6.6	1.2
2.....	.5	.3	11.....	8.0	1.4
3.....	1.0	.5	12.....	9.8	1.8
4.....	1.6	.6	13.....	12.0	2.2
5.....	2.2	.6	14.....	14.4	2.6
6.....	2.8	.6	15.....	17.2	2.8
7.....	3.5	.7	16.....	20.2	3.0
8.....	4.4	.9	17.....	23.4	3.2
9.....	5.4	1.0			

After the early years, growth increases rapidly and is maintained at a good rate until late in life. In the sapling stage a growth of 3 feet and over a year is not unusual. At the age of 50 the average dominant tree is still growing 1.7 feet per year, and at 100 years as much as 1 foot. At these ages the height growth of spruce compares very favorably with that of Douglas fir. This comparison is made from the available growth tables for the species mentioned, under conditions representative for each species, and not by comparison of the several species growing side by side on the same site.



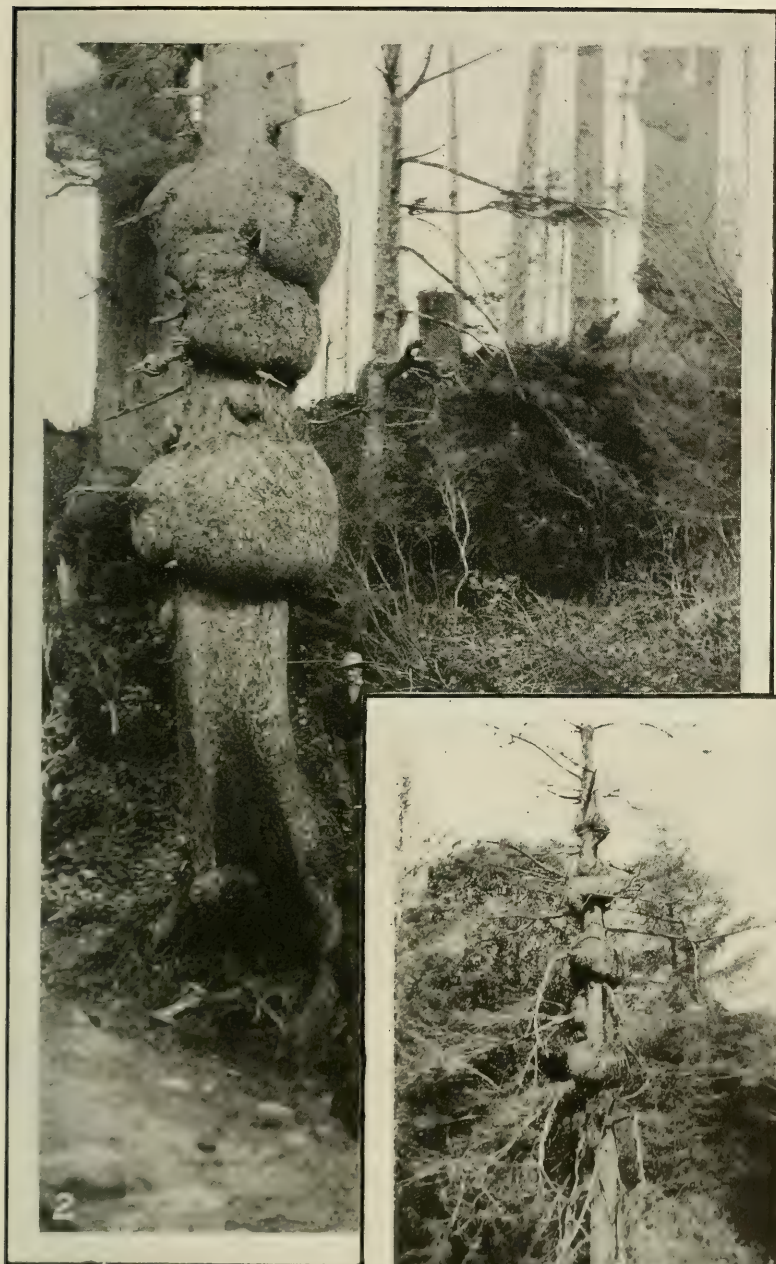
P-NIC-17

END VIEW OF SPRUCE LOG INFECTED WITH TRAMETES PINI.



F-NLC-18

HEAVY WINDFALL DAMAGE AT EDGE OF CUTTING IN 175-YEAR-OLD STAND NEAR TSILTCOOS LAKE, OREG.



F-ZLC 20

FIG. 2.—HUGE BURLS COMMON
ALONG THE COAST NEAR
NEWPORT, OREG.



F-NLC 19

FIG. 1.—ABNORMAL GROWTH IN SPRUCE.



PLATE XX

END SECTION OF SITKA SPRUCE LOG, SHOWING SUSTAINED DIAMETER GROWTH.

The figures given in Table 6 indicate the average total height and average annual height growth in each decade of older spruce of various ages, averaged from the measurement of 554 dominant trees. The figures are dependable for trees up to 300 years; beyond that age reliable height-growth figures are difficult to obtain, because very old spruce trees are commonly stag-headed.

TABLE 6.—Average total height at various ages, and average annual height growth in each decade of Sitka spruce on all sites in Oregon and Washington.

[Based on 1,260 sectional measurements of 554 dominant trees.] (Curved.)

Age.	Average total height.	Average annual height growth in each decade.	Age.	Average total height.	Average annual height growth in each decade.
Years.	Fect.	Fect.	Years.	Fect.	Fect.
20.....	31	2.4	220.....	224	0.3
30.....	51	2.0	230.....	226	.2
40.....	70	1.9	240.....	228	.2
50.....	87	1.7	250.....	230	.2
60.....	104	1.7	260.....	232	.2
70.....	119	1.5	270.....	233	.1
80.....	132	1.3	280.....	234	.1
90.....	144	1.2	290.....	235	.1
100.....	154	1.0	300.....	236	.1
110.....	164	1.0	310.....	236	.1-
120.....	173	.9	320.....	236	.1-
130.....	181	.8	330.....	237	.1-
140.....	188	.7	340.....	237	.1-
150.....	194	.6	350.....	237	.1-
160.....	200	.6	360.....	237	.1-
170.....	205	.5	370.....	237	.1-
180.....	210	.5	380.....	238	.1-
190.....	214	.4	390.....	238	.1-
200.....	218	.4	400.....	238	.1-
210.....	221	.3			

DIAMETER.

Diameter growth in this species is remarkably rapid and well sustained, as the figures in Table 7 indicate. In this table the figures represent the average of measurements taken of 557 dominant trees from seven localities in Oregon and Washington. Although its annual rate of diameter growth culminates at about the age of 40 years, it maintains a growth of over 3 inches per decade up to about 60 years, and thereafter for a few decades over 2 inches per decade. At the advanced age of 400 years, the data in Table 7 indicate, the diameter is still increasing at the rate of over 1 inch per decade. Exceptionally rapid diameter growth is attained on wet sites, where sometimes it may amount to three-quarters and even 1 inch annually during early years of vigorous growth. Plate XX shows the diameter growth of Sitka spruce.

TABLE 7.—Average diameter outside bark at 15 feet above ground at various ages and average annual diameter growth in each decade of Sitka spruce growing on all sites in Oregon and Washington.

[Based on measurement of 557 dominant trees.]

(Curved.)

Age.	Average diameter.	Average annual diameter growth in each decade.	Age.	Average diameter.	Average annual diameter growth in each decade.
Years.	Inches.	Inches.	Years.	Inches.	Inches.
20.....	2.0		220.....	43.4	0.14
30.....	5.6	0.36	230.....	44.8	.14
40.....	9.5	.39	240.....	46.2	.14
50.....	12.8	.33	250.....	47.5	.13
60.....	15.7	.29	260.....	48.8	.13
70.....	18.2	.25	270.....	50.1	.13
80.....	20.5	.23	280.....	51.4	.13
90.....	22.5	.20	290.....	52.7	.13
100.....	24.4	.19	300.....	54.0	.13
110.....	26.3	.19	310.....	55.3	.13
120.....	28.1	.18	320.....	56.6	.13
130.....	29.9	.18	330.....	57.8	.12
140.....	31.5	.16	340.....	59.0	.12
150.....	33.1	.16	350.....	60.2	.12
160.....	34.7	.16	360.....	61.4	.12
170.....	36.2	.15	370.....	62.5	.11
180.....	37.7	.15	380.....	63.6	.11
190.....	39.2	.15	390.....	64.7	.11
200.....	40.6	.14	400.....	65.8	.11
210.....	42.0	.14			

Diameter measurements at breast height are of little value in a Sitka spruce growth study, as this species commonly has a pronounced basal swell and its root base is usually well above the general ground level, owing to its habit of starting on down logs. For these reasons, in Forest Service timber survey work in spruce, diameters are taken at a point 1 foot above the swell; but this is a variable height and can not be used in growth studies when the relation between age and diameter is desired. In Table 7, therefore, diameters are given for a distance 15 feet above the ground and on most trees this point is above the basal swell. It must be borne in mind, however, that this uniform height above ground does not mean a uniform distance between this point and the root bases of all the trees measured. Trees which started on fallen logs 4 or 5 feet in diameter naturally have their root bases 4 or 5 feet above the ground, and the number of annual rings showing at the 15-foot point in these trees is, of course, less than at this point on trees whose root bases rest on the ground. It was found, however, that the discrepancy for all the trees measured amounted to only two years. This variation is rendered of little consequence by the rapid height growth of Sitka spruce in its sapling stage, when 3 feet per year is not an unusual growth. Another point that must be kept in mind in this connection is that it takes an average of 14 years for the seedling to reach a height of 15 feet, as shown by Table 5, and therefore a tree must be more than 14 years old before it shows diameter at this point of measurement.

VOLUME.

The volume growth of Sitka spruce is also rapid and well sustained. Table 8 indicates the average diameter, height, and volume, and the average volume growth that may be expected of dominant Sitka spruce trees in the spruce region of Oregon and Washington. The figures for diameter, height, and board-foot volume were taken from Tables 6, 7, and 11. Those for cubic-foot volume were supplied from a tree diagram in which the figures for average diameters and heights were combined with complete stem analyses of 10 dominant trees.

As indicated in this table, the periodic annual volume increment of spruce at 100 years exceeds 5 cubic feet, and at 300 years it is double this amount. The periodic annual growth continues greater than the mean annual for a long time after 300 years. At 100 years of age the volume of the entire stem without bark of dominant Sitka spruce trees approaches the high figure of 300 cubic feet, and at 200 and 300 years it exceeds 1,000 and 2,000 cubic feet respectively.

TABLE 8.—Average diameter, height, and volume and average volume growth of dominant Sitka spruce trees in Oregon and Washington.

Age.	Size.		Volume.		Annual volume growth.			
	D. o. b. at 15 ft.	Total height.	Entire stem without bark.	From stump height to top d. i. b. of 10 inches.	Periodic.	Mean.	Periodic.	Mean.
Years.	Inches.	Feet.	Cu. ft.	Bd. ft.	Cu. ft.	Cu. ft.	Bd. ft.	Bd. ft.
20.....	2.0	31	3		0.15	0.15		
40.....	9.5	70	22		.9	.5		
60.....	15.7	104	87	260	3.2	1.4		4
80.....	20.5	132	175	670	4.4	2.2	20	8
100.....	24.4	154	279	1,230	5.2	2.8	28	12
120.....	28.1	173	400	1,960	6.0	3.3	36	16
140.....	31.5	188	538	2,760	6.9	3.8	40	20
160.....	34.7	200	690	3,690	7.6	4.3	46	23
180.....	37.7	210	859	4,640	8.4	4.8	47	25
200.....	40.6	218	1,036	5,660	8.8	5.2	51	28
220.....	43.4	224	1,219	6,720	9.2	5.5	53	30
240.....	46.2	228	1,417	7,800	9.9	5.9	54	32
260.....	48.8	232	1,617	8,940	10.0	6.2	57	34
280.....	51.4	234	1,818	10,040	10.0	6.5	55	36
300.....	54.2	236	2,020	11,170	10.1	6.7	56	37

YIELD.

The yield of Sitka spruce per acre in the virgin forest varies considerably with its representation as a species in the stand, with the density of stocking, and with the quality of site. Although available data are not sufficient to furnish yield tables for the wide range

of conditions which obtain in the virgin forest, it is possible to give an idea of what may be expected under average conditions. The number of trees and the yield per acre in Table 9 are based on the averaged and curved values of twelve sample plots from one-half to 5 acres in size. On six of these plots Sitka spruce made up 88 to 100 per cent of the stand by volume; on five of them it made up 50 to 82 per cent, and on one plot it comprised 25 per cent. The plots were in essentially even-aged stands, except that the older stands contained an underwood of younger hemlock and cedar trees.

TABLE 9.—Average yield per acre of stands of Sitka spruce and associated species on good quality sites in Oregon and Washington.

(Curved)

Age.	Trees per acre.	Yield per acre.	Mean annual growth.	Age.	Trees per acre.	Yield per acre.	Mean annual growth.
<i>Years</i>		<i>Board feet</i>	<i>Board feet</i>	<i>Years</i>		<i>Board feet</i>	<i>Board feet</i>
40.....	400	29,500	734	180.....	82	140,000	778
60.....	280	54,250	904	200.....	70	144,750	724
80.....	220	78,000	975	220.....	60	148,250	674
100.....	175	99,500	995	240.....	50	151,000	629
120.....	130	115,000	958	260.....	42	153,000	588
140.....	112	126,000	900	280.....	36	154,250	551
160.....	94	134,000	838	300.....	30	155,500	518

As represented by the figures in this table, the yield of spruce stands compares well with that of Douglas fir on the best sites. Up to 90 years it makes a better yield, at 100 years it equals, and thereafter it falls a little behind Douglas fir.¹⁶ The yields of the table are those of the virgin forest; if proper methods of forest management were employed, and if the trees were thinned at regular intervals, these yields would be considerably increased. The rapid increment of Sitka spruce is especially evident when the periodic annual growth is considered, which between the ages of 40 and 60 years is 1,237 board feet.

MANAGEMENT.

Since Sitka spruce does not ordinarily grow in pure stands, but rather in intimate mixture with several other commercial trees, the principle of management which must be applied to spruce should be equally applicable to its associates—fir, hemlock, and cedar. The entire forest of which Sitka spruce forms a part must be treated uniformly. Hence the discussion of the management of spruce is interwoven with considerations of the other trees in the stand.

It has been shown that Sitka spruce is a very excellent timber tree, that its wood is superior to that of all others in the region for certain

¹⁶ Manuscript report by E. J. Hanzlik, Forest Service, Mar. 14, 1912.

purposes, that the tree has habits of growth and hardness that recommend it as a tree for the forester to favor and propagate for the forests of the future. It should be the objective, therefore, of timbermen and foresters so to manage spruce lands that they may become reforested through natural seeding, and that the new crop may contain a desirable admixture of Sitka spruce wherever this species will thrive.

Much of the land upon which the virgin forests of spruce occur has agricultural value and will be put to that use after the removal of the timber. On such lands no effort need be made by the forester or lumberman to promote a new crop to take the place of the one removed, but on all other lands this should be done.

The rapid extension of logging operations in this type makes very timely a discussion of methods of forest management which will insure continuous crops of timber.

OWNERSHIP.

The present ownership of the commercial Sitka spruce is shown in Table 10.

TABLE 10.—*Ownership of Sitka spruce timber, by classes of owners, in millions of feet, board measure.*

Ownership.	Washington.	Oregon.	California.	Alaska.	British Columbia.
Federal ¹	1,550	300	(²)	15,000- 18,000	.....
State.....	720	(²)	(²)	.....	1,423
Private.....	4,205	4,074	187	(²)	12,742
Total.....	6,475	4,374	187	15,000- 18,000	14,165

¹ Including Indian reservation.

² Negligible amount.

From the above it is seen that in Alaska the Sitka spruce forests are practically all under Federal control, but that in Washington, Oregon, and California the bulk of this timber is in private ownership. The perpetuation of forests of Sitka spruce and their future welfare are largely in the hands of private owners and not under the jurisdiction of public agencies of government. Many of the holdings have been consolidated into units of 1,000 to 30,000 acres, though small properties are not uncommon. The State lands of Washington are in various-sized blocks, which in the aggregate now amount to about 10,000 acres. The Sitka spruce timberlands under Federal control in Washington lie chiefly in the Olympic National Forest and

in the Quinault Indian Reservation. In Oregon they are confined to the Siuslaw National Forest and several military and lighthouse reservations.

FIRE PROTECTION.

The most important factor in the management of the Sitka spruce type is fire protection. Without effective fire protection all other steps in forest conservation are useless. The virgin forests of the Sitka spruce type in the coastal belt are perhaps less likely to suffer from fire than the Douglas fir forests of the Cascade Range, but they are by no means immune. Systematic organized fire protection during the two or three dry summer months is essential for the safety not only of the virgin forest but also of the new crop of reproduction which follows logging. In the course of lumbering, special precautions should be taken by operators to prevent the escape of fire, for an accidental and uncontrolled fire in dry slashings may gain such headway that it will do great damage to adjoining standing timber and especially to areas of second-growth timber on older cuttings.

METHOD OF CUTTING.

Clear cutting is the method of logging universally employed in the spruce region; it is the only method practicable in these dense forests of very large trees. Moreover, Sitka spruce and western hemlock when isolated by the removal of a part of the stand are so subject to windthrow that any method of reserving seed trees of these species or of making a selection cutting is technically undesirable. Steam logging, moreover, fits in well with the requirements of the species, except so far as it increases the fire hazard, for it helps to expose the mineral soil.

SLASH DISPOSAL.

Slash disposal in the heavy forests of the Pacific coast region means the elimination of slash by broadcast burning. The objects are to reduce the fire hazard in the débris left after logging, to provide a proper seed bed for reproduction, and to retard the spread of insect and fungous diseases.

By far the most important of the above objects is to reduce the fire hazard. Since this is so the necessity for burning slash depends largely upon the fire menace of the region. Although in the spruce belt of Oregon and Washington the rainfall is abundant and fogs are frequent throughout most of the year, there are two months or more in the summer when slashings become dry, and uncontrollable fires may start and do untold damage. Because of this Sitka spruce slashings in this region should ordinarily be burned.

In Alaska, on the other hand, the danger of forest fires in the spruce belt is not great even in old cuttings because of frequent and heavy rains in the summer as well as throughout the rest of the year. Slash burning, therefore, is unnecessary and, moreover, highly undesirable, because it destroys the layer of humus and duff with which the rock is all too scantily covered in that thin-soiled country. Foresters recommend that in Alaska the slash be lopped and allowed to lie, and this is the required practice after logging on the national forests of the Territory.

If slash is to be burned in Sitka spruce stands, it is very important that it should be done the first spring or fall following logging, so that the crop of seedlings which springs up in the first growing season after cutting will not be killed by the fire. Slash burning should also be done at a time when the weather conditions are such that the fire can be held in control on the area which it is intended to burn. Further, the slash fire should be hot enough to clean up all the inflammable débris.

PROVISIONS FOR REPRODUCTION.

Studies of old cuttings indicate that Sitka spruce reproduction ordinarily follows the removal of the virgin forest, unless the area has been subjected to repeated fires. Reproduction is abundant where the slash has not been burned at all, as well as where there has been but one slash fire immediately after logging. Sitka spruce seems to be represented in the reproduction in as abundant proportions as it was in the original forest. It is apparent that this abundant reproduction following logging comes from seed which had accumulated in the ground before the virgin timber was cut, had escaped injury from fire (if the slashing was burned), and had germinated when the forest floor became exposed to the light and warmth of the sun's rays. Because of this adequate store of seed in the ground, special provisions for leaving spruce seed trees is not essential, provided only that the area is effectively safeguarded from fires after this seed germinates. As a precaution in case of an accidental fire, and as an added assurance of natural reproduction, it is well to leave occasional seed trees of such wind-firm associated species as Douglas fir, choosing those which are good seed producers. It is not ordinarily advisable to leave single seed trees of Sitka spruce, for they are too likely to be wind thrown. To secure some of this species in the next crop, reliance must be placed on the seed stored in the forest floor and released by the cutting of the virgin forest.

If natural reproduction does not restock an area adequately, it may occasionally be advisable in the interest of good management

to renew the forest artificially by seeding or by planting nursery-grown trees. This may be advisable if repeated fires have so denuded the land of seed trees and of reproduction arising from stored seed that there is no way for the natural regeneration of the stand to take place except by the slow process of migration from the surrounding timber. Methods of artificial reforestation of Sitka spruce are in general similar to those employed for Douglas fir. Occasionally successful results may be obtained from the direct sowing of seed on the denuded area, either broadcast or in specially prepared spots. This method, however, is very uncertain because of the likelihood of the seed being destroyed by birds or rodents and because of the heavy mortality which frequently occurs among the young seedlings during the first years after germination. Planting nursery-grown trees is a more dependable method, and while the initial expense may be greater than that of direct seeding, it may prove to be cheaper in the end. The use of 3-year-old transplant stock is recommended. On the better quality of sites Sitka spruce may be planted pure over relatively small areas; but, since it more commonly occurs associated with other species, a mixture of spruce with Douglas fir or hemlock is usually preferable. The composition of the former stand should largely govern the choice of species.

ROTATION.

A relatively short rotation is possible in Sitka spruce forests because of their rapid growth. Crops suitable for pulpwood might be produced on the best sites in 40 years or less, and crops for saw timber in twice that period. Information on the growth rate of the Alaskan forests is meager, but the indications are that a somewhat longer period will be required to produce timber suitable for various purposes than is needed in Oregon and Washington.

APPENDIX.

TABLE 11.—Volume table for Sitka spruce in Oregon and Washington.

This table is based on the measurement in 1914 and 1919 of 450 felled Sitka spruce (*Picea sitchensis*) trees, grown in fully stocked stands, averaged for all sites and seven localities at elevations from sea level to 1,200 feet, and from southern Oregon to northern Washington. Trees were scaled by Scribner Decimal C rule to a top diameter of 10 inches inside bark; actual height of stump was used (it averaged 8 feet); logs were scaled in 32-foot lengths and less, plus an allowance of 0.5 foot for trimming. The table was constructed by the frustum form factor method and volumes curved. Trees are classified according to their diameter outside bark at 1 foot above pronounced basal swell, which was found to average 8 feet above ground. No allowance is made for defect or breakage. Breakage in 184 trees amounted to less than 2 per cent of merchantable volume.

Diam-eter above swell.	Aver-age. ¹	Number of 32-foot logs.											Basis.	
		2	2½	3	3½	4	4½	5	5½	6	6½	7		7½
		Total height in feet.												
		112	128	142	158	173	188	202	217	231	241			
Volume in board feet in tens.														
Inches.													No. trees.	
12	5	26											3	
14	12	28											14	
16	19	30	41										14	
18	26	34	46	59									24	
20	40	39	53	69	83								27	
22	58	45	60	79	96	111							31	
24	83	51	69	90	109	129							24	
26	108	56	78	102	123	147	172	198					28	
28	140		88	115	139	167	195	226	255				27	
30	178		98	130	158	188	220	254	287				31	
32	219		110	144	175	210	246	283	321	358			24	
34	269		123	158	195	234	273	314	355	406			30	
36	317			174	215	258	302	346	382	437			25	
38	374			191	237	283	330	379	430	479			31	
40	431			208	259	310	362	415	469	523			25	
42	493			224	283	338	394	452	511	570			13	
44	558			239	309	369	429	491	554	619	686		26	
46	622			255	335	400	464	532	601	671	742		20	
48	692				364	433	502	576	650	726	802	881	19	
50	768				395	466	542	622	702	783	866	951	18	
52	842					503	584	668	755	842	932	1,022	10	
54	916					538	626	718	810	904	999	1,096	13	
56	998						673	769	868	968	1,069	1,173	8	
58	1,081						718	821	926	1,034	1,147	1,253	5	
60	1,169						764	875	988	1,102	1,220	1,334	7	
62	1,250						811	930	1,051	1,172	1,295	1,418	4	
64	1,334						860	987	1,115	1,246	1,373	1,505	10	
66	1,423						911	1,045	1,182	1,320	1,454	1,597	7	
68	1,514							1,107	1,252	1,397	1,539	1,690	10	
70	1,609							1,168	1,323	1,474	1,630	1,786	7	
75	1,862								1,509	1,680	1,862	2,037	4	
80	2,126								1,707	1,904	2,102	2,301	4	
85	2,412									2,148	2,374	2,586	2	
90	2,714									2,424	2,656	2,891	2	
													450	

¹ When trees are not tallied by number of logs, use this column.

TABLE 12.—*Volume table for Sitka spruce in Behm Canal (Alaska) region.*

This table is based on taper measurements, in 1917, of 131 trees, total height and length of tip of 28 trees, and total height only of 92 trees which grew near Loring, Alaska. Figures indicate merchantable volumes, scaled by Scribner Decimal C rule, and represent contents from stump height of 2 feet and up to 6 inches d. i. b. at top. They are unreliable for trees over 44 inches in diameter. The table was prepared under the direction of R. E. Kan Smith.

Diameter breast-high.		Volume.	Diameter breast-high.		Volume.
<i>Inches.</i>		<i>Board feet in tens.</i>	<i>Inches.</i>		<i>Board feet in tens.</i>
24.....		82	46.....		400
26.....		101	48.....		445
28.....		132	50.....		491
30.....		154	52.....		536
32.....		166	54.....		587
34.....		192	56.....		639
36.....		219	58.....		686
38.....		250	60.....		736
40.....		283	62.....		784
42.....		318	64.....		837
44.....		357	66.....		890

TABLE 13.—*Log volume table for Sitka spruce in Oregon and Washington.*

This table was constructed from measurements of 234 felled Sitka spruce trees in Oregon and Washington (the majority of which grew along the Hump-tulips River in Washington). By means of the Scribner Decimal C rule the volume of each log and its percentage of the total merchantable volume in the tree were calculated, and these percentages were curved and applied to the merchantable volume of the average tree for each diameter class. Logs are in 32-foot lengths.

Diameter above a swell.	Total mer- chant- able volume.	Log volume and percentage of total volume.								Basis.
		Butt log.		Second log.		Third log.		Fourth log.		
Inches.	Bd. ft. in tens.	Bd. ft. in tens.	Per cent.	Bd. ft. in tens.	Per cent.	Bd. ft. in tens.	Per cent.	Bd. ft. in tens.	Per cent.	No. trees.
20.....	40	23	57.8	13	33.7	.....	.....	.....	.....	2
22.....	58	32	54.9	18	32.5	.....	.....	.....	.....	9
24.....	83	43	52.2	26	31.6	.....	.....	.....	.....	9
26.....	108	53	49.6	33	30.8	.....	.....	.....	.....	10
28.....	140	66	47.1	42	30.3	.....	.....	.....	.....	8
30.....	178	79	44.6	53	29.8	34	19.4	.....	.....	14
32.....	219	93	42.6	64	29.4	42	19.5	.....	.....	0
34.....	269	109	40.7	78	29.0	53	19.6	.....	.....	23
36.....	317	125	39.4	91	28.7	62	19.7	35	11.0	28
38.....	374	143	38.3	106	28.5	74	19.8	41	11.0	0
40.....	431	161	37.5	122	28.3	86	19.9	47	11.1	35
42.....	493	181	36.8	138	28.1	98	19.9	55	11.2	0
44.....	558	202	37.3	156	28.0	112	20.0	63	11.3	32
46.....	622	222	35.8	173	27.9	124	20.0	71	11.4	0
48.....	692	245	35.4	192	27.7	139	20.1	80	11.5	18
50.....	768	269	35.1	210	27.4	155	20.2	89	11.6	0
52.....	842	292	34.7	229	27.2	171	20.3	98	11.7	15
54.....	916	315	34.4	247	27.0	187	20.4	108	11.8	0
56.....	998	340	34.1	268	26.9	204	20.5	119	11.9	14
58.....	1,081	365	33.8	288	26.7	223	20.6	129	12.0	0
60.....	1,169	391	33.5	309	26.5	242	20.7	141	12.1	4
62.....	1,250	413	33.1	329	26.3	259	20.7	152	12.2	0
64.....	1,334	437	32.8	348	26.1	277	20.8	164	12.3	4
66.....	1,423	461	32.4	369	26.0	296	20.8	178	12.5	0
68.....	1,514	484	32.0	392	25.9	316	20.9	191	12.6	3
70.....	1,609	510	31.7	413	25.7	338	21.0	204	12.7	0
75.....	1,862	575	30.9	472	25.4	395	21.2	244	13.1	4

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TABLE 14.—Comparative diameters at breast height and above swell of Sitka spruce, based on maximum taper.

This table is based on maximum taper measurements of 37 trees which grew in Oregon and Washington. The figures under "taper" are inches per foot of vertical distance. The diameters above swell are noted for average heights of swell.

(Curved.)

Diameter breast-high.	Diameter above swell.	Average height of swell.	Taper.	Diameter breast-high.	Diameter above swell.	Average height of swell.	Taper.
Inches.	Inches.	Feet.	Inches.	Inches.	Inches.	Feet.	Inches.
60.....	51	7	3.5	110.....	76	12	4.5
65.....	56		3.5	115.....	80		4.6
70.....	61		3.6	120.....	85		4.7
75.....	66		3.7	125.....	89		4.8
80.....	67	8	3.8	130.....	93	12	4.9
85.....	71		3.9	135.....	97		5.0
90.....	76		4.0	140.....	102		5.1
95.....	72		4.1	145.....	106		5.2
100.....	77	10	4.2				
105.....	81		4.3				

TABLE 15.¹—Average total height of Sitka spruce on all sites in different parts of Oregon and Washington.

(Curved.)

Age.	Tsitlecos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
Years.	Total height in feet.						
20.....	22	20	48	32	28	38	31
30.....	44	34	66	52	48	60	51
40.....	62	51	82	70	66	85	70
50.....	82	70	96	85	83	110	87
60.....	100	89	109	98	99	130	104
70.....	118	106	122	110	114	147	119
80.....	134	121	133	120	127	161	132
90.....	148	134	144	130	141	173	144
100.....	158	147	155	139	154	183	154
110.....	168	157	165	148	166	192	164
120.....	176	167	173	156	176	201	173
130.....	184	175	181	164	186	209	181
140.....	190	183	188	171	194	216	188
150.....	196	190	194	178	201	222	194
160.....	200	196	199	184	205	227	200
170.....	205	201	204	190	213	232	205
180.....		205	208	196	218	236	210
190.....		210	212	201	223	240	214
200.....		213	215	206	227	244	218
210.....		216	217	210	230	246	221
220.....		218	220	214	234	249	224
230.....		220	222	218	236	251	226
240.....		222	223	221	239	252	228
250.....		224	225	223	241	254	230

¹ The following is a description of the localities in which the growth measurements were taken:
Tsitlecos Lake, Lane County, Oreg.—Pure stand of even-aged second growth (175 years) on gentle slopes, at elevation of 150 to 300 feet. Soil deep, loose, sandy to sandy loam; moist but well drained.
Newport, Lincoln County, Oreg.—Three types; 130-year-old pure stand on moist, well-drained flat at 200-foot elevation in deep sandy loam; 320-year-old stand mixed with young hemlock on slopes, 300 to 350 feet above sea level in deep, well-drained sandy loam; and 300-year-old mixed stand in wet clay loam of creek bottom, 25 to 50 feet in elevation.
Clatsop, Clatsop County, Oreg.—Two types; 300-year-old pure stand on gentle slopes at altitudes of 900 to 1,100 feet, deep, moist, well-drained clay loam; 300-year-old stand in mixture with hemlock on level ground of wet clay loam at altitude of 400 feet.
Raymond, Pacific County, Wash.—Two types; small groups of even-age, varying between 110 and 440 years, on slopes of moderate pitch, well drained, deep, and of clay loam; parklike stand on poorly drained flat, at elevation of 250 to 300 feet.
Hoquiam, Grays Harbor County, Wash.—Two types; 250-year-old pure stand on moist, well-drained flat, at 400 feet elevation, in heavy soil underlain with gravel; 350-year-old stand in mixture on wet poorly drained flat, of clayey soil at same elevation.
Beaver, Clallam County, Wash.—Three hundred-year-old, pure stand in very moist, level, creek basin of rich alluvial soil at altitude of 600 feet.

TABLE 15.—Average total height of Sitka spruce, etc.—Continued.

Age.	Tsiltcoos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
Total height in feet.							
Years—Continued.							
260		225	226	225	242	255	232
270		227	227	227	243	256	233
280		228	228	229	244	258	234
290		229	229	230	245	259	235
300		230	230	231	246	260	236
310		230	231	232	246	.....	236
320		231	231	232	246	.....	236
330		231	231	232	247	.....	237
340		231	232	233	247	.....	237
350		232	232	233	247	.....	237
360		232	232	233	248	.....	237
370		232	232	234	248	.....	237
380		232	233	234	248	.....	238
390 .....		.....	233	234	249	.....	238
400 .....		.....	234	234	249	.....	238
Basis: Number of measurements.....	220	189	220	311	138	182	1,260

TABLE 16.¹—Average diameter outside bark at 15 feet above ground of Sitka spruce on all sites in different parts of Oregon and Washington.

(Curved.)

Age.	Tsiltcoos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
Diameter in inches outside bark at 15 feet.							
Years.							
20	1.7	2.3	3.2	1.6	2.2	3.4	2.0
30	5.5	6.3	7.2	4.4	5.2	8.3	5.6
40	9.1	10.0	11.1	7.2	8.3	12.4	9.5
50	13.0	13.7	14.1	9.7	11.2	16.2	12.8
60	16.6	16.8	16.5	12.3	13.7	19.2	15.7
70	19.7	19.7	18.5	14.7	15.9	21.7	18.2
80	22.3	22.3	20.4	16.9	18.1	23.9	20.5
90	24.6	24.6	22.1	19.1	20.1	25.8	22.5
100	26.6	26.6	24.8	21.2	22.0	27.8	24.4
110	28.4	28.6	25.5	23.3	23.7	29.5	26.3
120	30.1	30.3	27.2	25.4	25.4	31.0	28.1
130	31.5	31.8	28.8	27.6	27.2	32.5	29.9
140	32.8	33.2	30.3	29.7	28.8	33.8	31.5
150	34.3	34.8	32.8	31.8	30.4	35.2	33.1
160	35.6	36.6	33.3	34.0	32.0	36.4	34.7
170	36.9	37.7	34.9	36.1	33.6	37.8	36.2
180	38.2	39.1	36.4	38.2	35.1	39.0	37.7
190 .....	.....	40.3	37.8	40.3	36.7	40.2	39.2
200 .....	.....	41.7	39.3	42.4	38.2	41.3	40.6
210 .....	.....	43.0	40.7	44.6	39.7	42.2	42.0
220 .....	.....	44.3	41.9	46.7	41.2	43.3	43.4
230 .....	.....	45.5	43.1	48.7	42.7	44.2	44.8
240 .....	.....	46.7	44.2	50.5	44.2	45.2	46.2
250 .....	.....	47.8	45.3	52.3	45.7	46.1	47.5
260 .....	.....	48.8	46.3	54.0	47.8	47.1	48.8
270 .....	.....	49.8	47.3	55.4	48.7	48.0	50.1
280 .....	.....	50.8	48.3	56.8	50.1	48.9	51.4
290 .....	.....	51.8	49.3	58.0	51.6	49.7	52.7
300 .....	.....	52.8	50.3	59.3	52.9	50.6	54.0

¹ For description of localities see footnote to Table 15.

TABLE 16.—Average diameter outside bark at 15 feet above ground of Sitka spruce on all sites in different parts of Oregon and Washington—Continued.

Age.	Tsiltcoos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
Diameter in inches outside bark at 15 feet.							
Years—Continued.							
310.....		53.8	51.4	60.5	54.4	.....	55.3
320.....		54.8	52.4	61.7	55.8	.....	56.6
330.....		55.7	53.5	62.8	57.2	.....	57.8
340.....		56.7	54.5	64.0	58.6	.....	59.0
350.....		57.5	.....	65.1	60.0	.....	60.2
360.....				66.2	61.4	.....	61.4
370.....				67.3	62.8	.....	62.5
380.....				68.4	.....	.....	63.6
390.....				69.6	.....	.....	64.7
400.....				.....	.....	.....	65.8
410.....				.....	.....	.....	67.2
Basis: Number trees.....	95	78	100	133	73	78	557

TABLE 17.—Results of tests on Sitka spruce wood from Washington, in green and air-dry condition, in the form of small clear pieces.¹

[From Table 1, U. S. Dept. Agr. Bull. 556.]

Mechanical property.	Green condition.	Air-dry condition.
Number of rings per inch.....	9	9
Summerwood (per cent).....	24	24
Moisture content (per cent).....	53	8.9
Specific gravity, based on volume and weight when oven-dry.....	.37	.38
Weight per cubic foot (pounds).....	33	26
Shrinkage from green to oven-dry condition:		
Radial (per cent).....	4.5	.....
Tangential (per cent).....	7.4	.....
Static bending:		
Fiber stress at elastic limit (pounds per square inch).....	3,000	7,200
Modulus of rupture (pounds per square inch).....	5,500	11,200
Modulus of elasticity (1,000 pounds per square inch).....	1,180	1,610
Work to maximum load ² (inch pounds per cubic inch).....	6.4	10.4
Compression parallel to grain:		
Maximum crushing strength (pounds per square inch).....	2,600	5,770
Compression perpendicular to grain:		
Fiber stress at elastic limit (pounds per square inch).....	330	1,010
Shearing strength parallel to grain (pounds per square inch).....	780	1,210
Tension perpendicular to grain (pounds per square inch).....	230	.....
Hardness, side:		
Load required to embed 0.444-inch ball to one-half its diameter (pounds).....	370	530

¹ Test specimens were 2 inches by 2 inches in section. Bending specimens were cut 30 inches long; others were shorter, depending on test.² Work to maximum load represents the shock-absorbing ability of the wood.

LUMBER GRADES.

The following lumber grades are in use for different Sitka spruce products:¹⁷

Finish: B and Better.	Partition: B and Better.
Flooring: B and Better.	Bevel siding: A, B, C.
Ceiling: B and Better.	Wagon-box sets: B and Better.
Stepping: B and Better.	Boards and strips: Selected Common,
Battens: B and Better.	No. 1 Common.

¹⁷ For further information, see West Coast Lumberman's Association, "Rule 2: Standard Classification, Grading, and Dressing Rules for Douglas Fir, Sitka Spruce, Cedar, and Western Hemlock Products," January 22, 1922.

Dimension, plank, and small timbers:	Car siding and roofing: B and Better.
Selected Common, Common.	Ladder stock: Special Grade.
Lath: Standard Grade.	Cut-up sash and door stock: No. 1,
Turning squares: Standard Grade.	No. 2.
Molding stock: Standard Grade.	Piano posts: Special Grade.
Panel stock: No. 1, No. 2.	Sounding-board stock: Special Grade.
Factory lumber: Select Factory, No. 1	Box lumber: No. 1, No. 2, No. 3.
Shop, No. 2 Shop, 1-inch Shop Com-	Airplane stock: Special Grade.
mon.	Flitches: Special Grade.

LOG GRADES IN BRITISH COLUMBIA.¹⁸

SPRUCE, PINE, AND COTTONWOOD.

No. 1: Logs 12 feet and over in length, 30 inches in diameter and over, up to 32 feet long, 24 inches if over 32 feet long, reasonably straight, clear, free from such defects as would impair the value for clear lumber.

not > No. 2: Logs less than 14 inches in diameter and not over 24 feet long, or not less than 12 inches in diameter and over 24 feet long, sound, reasonably straight, free from rotten knots or bunch knots, and the grain straight enough to insure strength.

No. 3: Logs having visible defects, such as bad crooks, bad knots, or other defects that would lower the grade of lumber below merchantable.

Cull: Logs lower in grade than No. 3 will be classed as culls.

¹⁸ "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 170, 1918.

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A well-stocked, second-growth longleaf pine stand, 70 years old, on a farm in Tattnall County, Ga. The trees average about 70 feet in height and range up to 15 inches in diameter; they contain a total of about 30,000 board feet per acre of saw timber. The present owner grew up on the farm and remembers the trees when they were saplings about 10 years old. The location is within a few miles of the railroad, and attractive offers have repeatedly been made to the owner for the timber to be used as piling and lumber and for turpentine. Fires have largely been kept out.



FIG. 1.—Here is going on the complete removal of the forest cover with no hope of its returning naturally. After being cupped for two years, practically every pine is cut for saw timber or pulpwood. The tops and culls are being worked up into pulpwood; but regrettably, all the small young trees down to 4 inches are being taken. This type of logging, with the exception of the close utilization, is widely practiced over the longleaf belt.



FIG. 2.—The South has some 30,000,000 acres of waste and idle land suitable for producing 100 to 400 board feet of longleaf pine yearly, together with a steady yield of turpentine. In the development of the country's resources these lands are bound to be among the South's greatest assets.

THE PASSING OF THE LONGLEAF FOREST.



BULLETIN No. 1061



Contribution from the Forest Service
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Washington, D. C.



July 29, 1922

LONGLEAF PINE.

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Longleaf pine is a southern forest tree of great economic importance. It is one of our best timber trees, and from it is derived the bulk of the turpentine and rosin produced in this country. With the rapid disappearance of old-growth timber, the increasing use of low-grade lumber, and the rising values of all forest products, second-growth pine is coming to be an asset of increasing importance.

Large areas of cut-over lands are being handled in connection with the farming and grazing industries. On account of the natural wide spacing of longleaf pine trees, the grazing of live stock can be successfully carried on along with the growing of timber, without injury to either industry, as a double source of return from the land. Almost daily new uses and new values are being found for forest products formerly considered valueless. Questions on how to get the most profit from second-growth pine are being frequently asked. To the owner of large timber holdings, as well as to the farmer, the importance and value of second-growth pine are coming to be matters of increasing consideration.

The common belief that longleaf pine is slow growing applies only to old-growth or mature timber, and to that growing on unfavorable situations, such, for example, as the very dry sand hills and the flat-woods. It is likewise true of stands that are burned frequently, and of those that are overcrowded and in need of thinning. The seed germinates quickly—usually in two to four weeks after it matures in the fall. Contrary to the popular belief, when sufficient seed trees are left, young longleaf comes in extensively on cut-over lands, but the great bulk of it is killed by fires and hogs.

Longleaf pine is, however, remarkably resistant to fire. Millions of young trees not over 25 years of age have undoubtedly passed

through as many as 10 fires. Each fire, however, takes its toll of living trees and injures and retards the growth of all the others. Of the trees which survive, large numbers are being bled for turpentine or cut for timber at much too young an age to get the best money returns. Protection and forest management mean increased timber growth and increased profit.

Destructive lumbering and destructive fires are every year creating in the southern pine region millions of acres of waste and barren lands. In these idle timber lands is an enormous potential wealth, and their productive power is not fully realized. Economically, this condition is an unsettling factor just as serious as the idleness of thousands of farms or of factories. Forest growth should be encouraged on waste or idle lands and on lands not now in demand for agricultural use and not likely to be during the next half century, whether on farms or large cut-over tracts.

This bulletin deals not only with the forest conditions on the upper or higher portions of the Coastal Plain, where farming is relatively important, but it is also applicable to the flatwoods, where only 10 to 15 per cent of the land is in farms and the remainder mostly in the ownership of large lumber companies. Little attention will be given to old-growth timber, which is rapidly passing. The aim is to present the more useful information pertaining to the growth and value of longleaf pine, the production of timber and turpentine, the methods of cutting, reforestation, and protection of second-growth longleaf pine, and the ways of making tracts of land profitable which will remain idle for many years unless they are devoted to growing crops of turpentine and timber.

RANGE AND IMPORTANCE.

Longleaf pine is generally well known in the localities where it grows and is commonly distinguished from other species with which it is associated. In earlier life, the erect, stout, central stem, densely covered with leaves ("straw"), is one of its well-known characteristics. Later and through life it has a straight, clean shaft or trunk. The leaves are from 8 to 18 inches in length, pendulous, and occur in crowded clusters of three leaves each, forming the familiar-looking tufts toward the ends of the branches (Pl. III). The terminal buds are very large and almost white. The cones ("burs") vary in length from 6 to 10 inches—the longest of any of the southern pines—and, like all the pines, require two full seasons to reach maturity. The bark is orange-brown, and in mature trees separates on the surface into large, flat, irregular-shaped plates (Pl. IV) made up of thin scales. Fully grown trees reach heights of 70 to 120 feet, and diameters of 2 to 2½ feet or occasionally 3 feet. The trunk is notably straight, slightly tapering, and usually clear of limbs for one-half to two-thirds of its length.

The natural range of long-leaf pine (fig. 1) extends from southeastern Virginia, southward over the Atlantic and Gulf Coastal Plain to Florida and westward to eastern Texas. Commercially the range is very much less extensive. As a result of lumbering and repeated fires, there remains to-day probably less than one-fifth of the original stand of long-leaf pine, estimated to have amounted originally to over 400 billion board feet.

The largest remaining areas of old growth are found in the five States bordering on the Gulf of Mexico. Reports from mill operators



FIG. 1.—Outline map of the southern United States, the shaded part showing the botanical range of longleaf pine. This species of southern pine occurs widely distributed over the Coastal Plain from southeastern Virginia to eastern Texas. Extensive areas of cut-over longleaf lands occur throughout practically the whole range. The bulk of the remaining old growth is located in parts of Florida, Alabama, Mississippi, and Louisiana. Originally, longleaf pine composed the bulk of probably the world's greatest pure yellow pine forest.

owning or controlling practically the entire remaining stand of old-growth pine in the South indicate that it is very doubtful whether at the present rate of cutting the longleaf forests, which have always been the chief factor in the production of southern yellow pine, will last for many years.

The total annual cut of longleaf is not known. According to the best estimates, the lumber cut is roughly about one-half of the total southern yellow pine lumber cut, which ranges yearly from 10 to 15

billion board feet. In addition, considerable amounts are cut for crossties, piling, pulpwood, and fuelwood. The estimated total cut is, therefore, equivalent to 8 to 10 billion board feet. Continuous losses of merchantable timber are caused by windfall, turpentine, insects, fires, and diseases.

Its habit of growth in pure stands over large areas, rather than as scattered trees in a mixture, and its ability to grow on poor, dry, and poorly drained soils mark longleaf as a pine of great potential value. Over its range, generally, longleaf pine is found growing on practically all soils except the very wet and the rich alluvial soils, which are variously occupied by cypress, mixed hardwoods, and slash, pond, or loblolly pines. Yellow pines have been and still are among the few important sources of wealth in the South. The original timber is going; but, with a recognition of the evil effects of fire and with a few essential precautions against it, this timber can be replaced with young growth, and the land will again come back in large measure to its former position of economic importance.

SECOND-GROWTH TIMBER.

The value of second-growth pine is becoming increasingly recognized as the main body of old growth is cut. Within the next 10 to 15 years this value will doubtless be widely recognized. Extensive purchases of second growth by investors might be expected in view of the history of the prices that have been paid and are being paid for small and often inferior timber growth in New England and the Lake States.

Second-growth pine has a distinct use and value (Pl. IV). Lumbermen, who have heretofore regarded themselves simply as manufacturers of boards, are coming to have an interest in the question of a future supply of logs, and during the past few years operators in various sections of the South have bought large tracts of land for the perpetuation of their industry. The underlying idea is to operate continuously on the same tract. The more progressive lumbermen regard favorably the buying of good stands of young timber because it affords a more profitable investment than holding old timber for 20 to 40 years. A relatively small amount of capital is tied up in the combined young timber and cut-over land, and often a greater return on the investment is possible.

Growth in mature timber is very slow and is offset by losses caused by insects, fungous diseases, fire, wind, and lightning. Young timber, on the other hand, is growing at a good rate and utilizing the productive capacity of the land. Merchantable stands are coming to be taxed at an amount nearer their full value. In young stands the trees that need to be cut out, in order to allow the remaining trees ample room for growth, yield cordwood, ties, poles, or pulp-



FIG. 1.—A heavy crop of longleaf pine cones bearing seed occurs widely over the South at intervals of about every 7 years. The flowers "set" early in the spring; the seeds require 2 years to mature, and are usually shed in September. Seed crops can thus be foretold more than a year ahead by observing the small green cones on the trees in the summer and fall during their season of development.

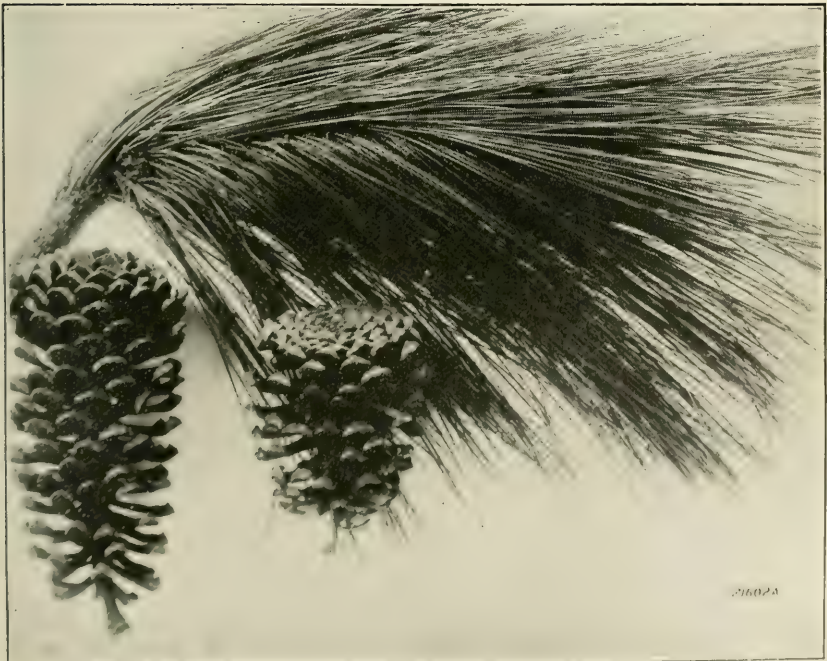


FIG. 2.—Foliage and cones ("burs") of the longleaf pine.

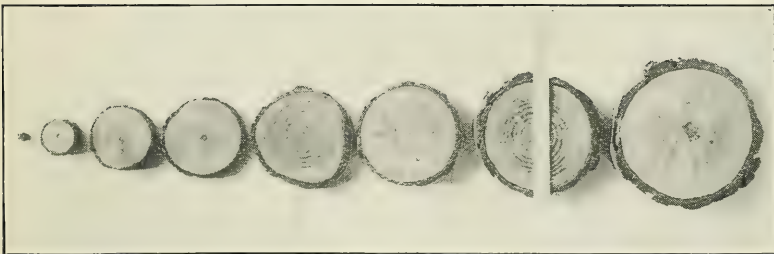


FIG. 1.—Sections cut from the average-sized tree in a well-stocked 48-year-old longleaf stand. (Plate IX, Fig. 2.) The tree measured 62 feet in height and 11 inches in diameter (outside bark) at breast-height.

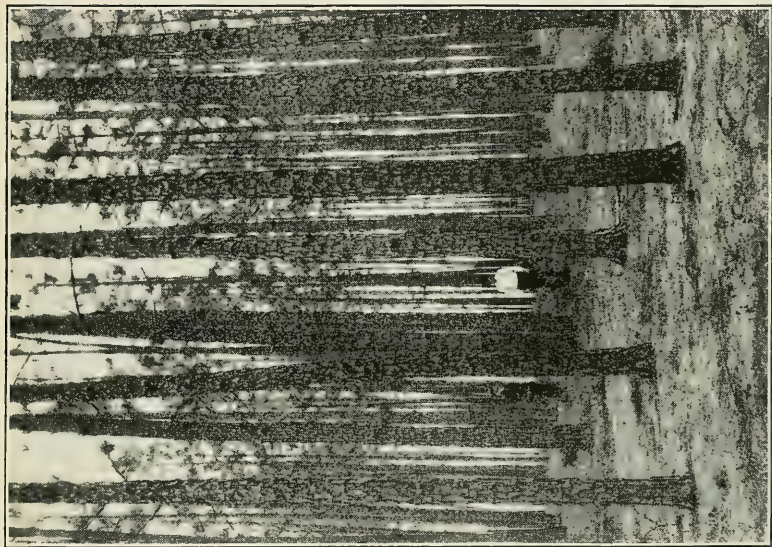


FIG. 2.—Products from farm timberland. This 40-year-old longleaf pine stand has for years supplied the owner with timber, wood, and pine straw. Located on a ridge of thin soil, in Telfair County, Ga., it has at the same time served as a protective windbreak. Note the even spacing and uniform development of the trees, the result of the owner's commendable practice of thinning out the poorer, suppressed, and crooked trees.



FIG. 3.—The smooth straight trunk of longleaf pine is well known over the range of its occurrence. One of its associates, slash pine, has a quite similar bark, while that of loblolly, another associated pine, is rough, with deep longitudinal furrows and ridges. Young-growth pine exhibits quite similar differences in the appearance

wood. Under "Cutting" the subject of thinning is discussed. Operators of turpentine have learned that second growth serves the purpose. Over considerable sections of the yellow pine region the lumber industry is now working on second growth.

Extensive areas in the South will not be put to their best use until they are growing well-stocked stands of young timber. It is inconceivable that a section of the country with such a vast area of natural forest soil could continue for any length of time in a state

One sawmill, that cuts mostly longleaf pine, requires daily the timber from about 100 acres, or yearly that from about 25,000 acres. About 6,000,000 acres of longleaf pine timber land, it is estimated, are cut in this country yearly, and about 4,000,000 acres are left fire-swept and practically idle. Is it not time steps were taken to remedy this situation? It is not a question of decreasing the rate of cutting the timber, but rather of stopping fire devastation and putting the nonproducing acres to work. Millions of acres of lands now denuded and nonproductive should be growing trees of use and value.

The supplies of coal, petroleum, and iron are limited, but not so with wood. A forest is not a thing to be exploited and then abandoned, but a property that under right management can be made to yield fair annual dividends in perpetuity.

Lumber should be among the cheapest of commodities, since with adequate forethought and care the forest becomes, like the air, water, and soil, an inexhaustible resource.

of prosperity with timber growing largely eliminated. Any sound economic policy for the region calls for the right use of the present forest resources and also for the adoption of public measures which will insure an income from all lands and a permanent supply of the raw products so essential to the progress and prosperity of the people. Cut-over forest land can be made to produce another forest as good or better than the original one. It thus follows that the use of timber and the reproduction of timber can go hand in hand, provided, of course, that the right steps are taken in accordance with the natural laws of tree growth.

Cut-over lands on which there are seed trees are worth more than denuded lands, for the reason that they are earning an income from the growth of the trees, which is accelerated by the increased supply of light and soil moisture, and from the constantly enhancing value of the young forest stands. It is claimed by some practical lumbermen that the value of such lands with young growth will be doubled within about 5 years after logging. These factors do not diminish the prospective value of these lands for agriculture or interfere to an appreciable degree with the use of the land for grazing. Lands that contain some timber are more valuable for farms than are "skinned" cut-over lands, because a supply of timber is available for sale and for home use, there is shade in the pastures, and the trees make the homes more attractive.

RATE OF GROWTH.

During the first 30 to 60 years of its life—the period under special consideration in this bulletin—and on the better soils or situations where it occurs, longleaf pine grows at a moderate to rapid rate. The general rating of longleaf as a slow-growing species of pine is the result of the almost exclusive handling and consideration of old timber, which grows at a slow or very slow rate.

The rate of growth shows wide variations, apparently related closely to differences in the depth and texture of the soil and its supply of soil moisture. Because many of the longleaf pine soils are subject to periods of extreme dryness, the slow growth in many natural unthinned stands and the comparatively wide spacing found in older longleaf stands are often attributed to the competition of the roots for soil moisture rather than of the branches for light. An important determining factor in the rate of growth of the individual trees is their density, or the number of trees per acre in the stand, at any specified age. Growth in diameter is particularly influenced by this condition.

During the first few years the growth of young seedlings consists chiefly in the development of a large root system. A very stout long taproot, accompanied by several large laterals and many smaller ones, underlies and supports a very short stem, crowned with a dense tuft of long, drooping, grasslike foliage. This period of apparently little activity is very deceptive and has been one cause of the general impression that longleaf is a very slow grower. Generally, from 3 to 5 years are required for longleaf to reach the height of 6 inches to a foot and develop the requisite root system for making the rapid "shoot" upward which follows. Under protection from fires, it is known that on loamy sand in the upper

Coastal Plain longleaf saplings at 5 years of age reach heights of 2 to 3 feet and at 7 years of 5 to 8 feet. The occurrence of fires at frequent intervals, usually of about 2 years, in different sections over practically the entire longleaf pine belt, and the accompanying marked effect in checking growth should not be overlooked in any consideration of the rate of growth.

Since the purpose here is chiefly to consider growth after the youngest or seedling stage, the germination of the seed and the early seedling development will be discussed under "Reforestation" in connection with getting young stands started.

The period of vigorous growth, during which the longleaf saplings "shoot" up rapidly, begins at an age of about 5 years and continues to about 20 to 25 years. At about 7 years, the height of saplings sometimes increases 3 to 4 feet during a single year. A growth of 2 feet a year in well-stocked stands is common over large areas (fig. 2 and Pl. V.), and open-grown trees on average good situations not uncommonly grow from 2 to 3 feet yearly. At the same time, the young trees grow to a diameter (at the ground) of about 2 inches during the 2 to 4 years following the early preparatory stage. Varying widely, longleaf saplings require 6 to 8 years on an average to reach breast height, or $4\frac{1}{2}$ feet above the ground. After the maximum rate of height growth, at an age prior to 20 years, the rate gradually diminishes. It should, however, be clearly understood that young longleaf pine trees, subjected to hot fires, do not grow at the rates indicated. On protected old fields in the flatwoods of eastern North Carolina, measurements of longleaf pines show that in 35 to 50 years the average trees produce saw logs 14 to 20 inches at the butt and 20 feet in length.* The usefulness of these pine trees, however, would begin a little earlier if they were turpentine, and the thinning out of the foliage would also encourage the incoming of the tender grasses which are valuable for pasturage. This may be considered as about the average of the better growth to be expected throughout the longleaf pine region. The soil conditions on old fields are favorable, probably because of changes taking place in the hardpan layer.¹

The most useful information regarding the rate of growth is obtained by measuring the amount of growth actually taking place in stands approximately even-aged and fairly well stocked. The trees in such stands grow tall, straight, and clean of branches, but relatively slow in diameter (Pl. IV). At any given age, therefore, the average trees in well-stocked stands will be considerably smaller

*By W. W. Ashe, formerly in charge of investigations, North Carolina Geological Survey.

¹ Studies by J. O. Veatch, Bureau of Soils, U. S. Department of Agriculture.

in diameter than those of similar age growing in the open. Likewise, at relatively early ages—at 30 years for example—an acre that was half stocked might have trees of saw-timber size, whereas a fully stocked stand might not have any trees of merchantable saw-timber sizes.

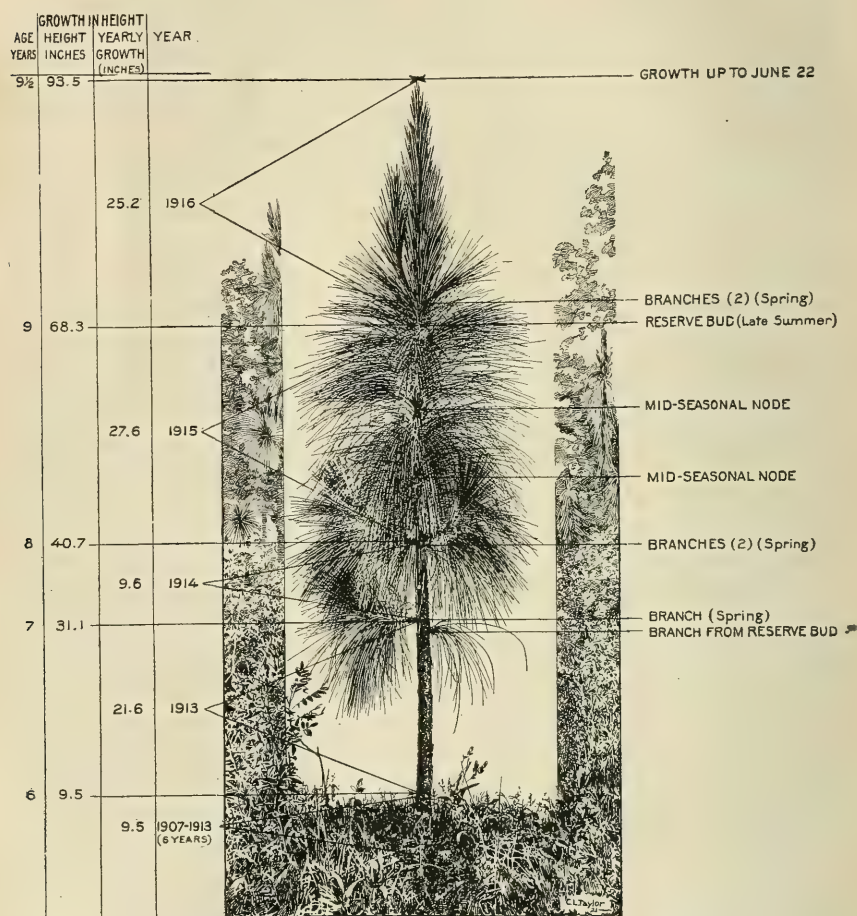


FIG. 2.—Natural growth of longleaf pine for the past 4 seasons under fire protection; nearly 8 feet tall in 9½ years. Photographed in June during period of rapid upward growth. (Jasper County, S. C.)

Table 1 shows, for different ages, the average height and diameter of longleaf pine trees growing in well-stocked, even-aged stands, on three different grades of land or situations. These figures, it is believed, are approximately representative of the rate of growth in stands of good density over the range of longleaf pine. They are based upon the measurement of selected portions of 78 longleaf pine stands whose locations range from South Carolina to Texas.

TABLE 1.—Average growth of trees in height, diameter, and number of trees per acre in well-stocked, even-aged longleaf pine stands on various qualities of land.

Age of stand.	Height.			Diameter ¹ (breast high).			Approximate number of trees per acre. ²
	Better land.	Medium land.	Poorer land.	Better land.	Medium land.	Poorer land.	
Years.	Feet.	Feet.	Feet.	Inches.	Inches.	Inches.	
15	39	24	10	5.3	3.6	1.9	550
20	50	34	19	7.0	5.0	3.1	450
25	58	42	27	8.1	6.0	4.0	393
30	63	48	33	9.0	6.9	4.8	355
35	68	54	39	9.7	7.6	5.5	328
40	72	58	43	10.4	8.3	6.2	308
45	75	61	46	10.9	8.8	6.7	293
50	78	64	49	11.4	9.3	7.2	280
55	80	66	52	11.8	9.6	7.5	270
60	82	68	54	12.1	10.0	7.8	264
65	83	69	56	12.4	10.2	8.0	258
70	84	70	57	12.7	10.4	8.2	254

¹ Diameters measured at breast height, or 4½ feet above the ground.

² The number of trees per acre varies considerably with age, but for any given age averages approximately the same on the better and poorer classes of land. Not only can the better lands support more trees of a given size, but the trees are much larger in size at any specified age than on unfavorable situations

On good lands, or good situations, it will be seen, for example, that at 20 years longleaf pine reaches heights averaging about 50 feet; on medium land, about 34 feet; and on poor land, about 19 feet. The medium class of land, for instance, would include the loamy sands of the middle and upper Coastal Plains, and the last class the poorer parts of the flatwoods and the very deep, dry sands. The corresponding diameters, depending upon the situation, range from 7 inches down to a little over 3 inches. During the next 10 years, the trees increase yearly in height at the rate of about 1.4 feet (16.8 inches) and in diameter nearly 2 inches. The average diameter, as shown, usually represents an actual range of 4 to 6 inches, or 2 to 3 inches greater and 2 to 3 inches less. Likewise, the average height would probably represent a range of 5 feet at 20 years and as much as 10 feet at 50 years. The average diameter at breastheight, for example, of trees in a 25-year-old stand on a medium grade of soil is shown to be about 6 inches, and the trees in that particular stand probably ranged in diameter mostly from about 8 inches down to 4 inches. Table 1 shows that longleaf trees growing in well-stocked stands on medium situations (land), have an average yearly height growth of about 17 inches at 25 years, 12 inches at 35, 6 inches at 50, and 4 inches at 60 years; and an increase in diameter at the rate of about 1 inch in 5 years at 25 years, in 7 years at 35, in 12 years at 50, and in 16 years at the age of 60 (fig.3).

There should be no misapprehension regarding the time necessary to grow a crop of pines to a size that is merchantable for timber or turpentine, or about the close relation existing between the number

of trees per acre (tree density) and the rate of growth of the trees in the stand. The number of longleaf trees per acre for well-stocked stands does not seem to be widely variable at any given age for the different classes of situations, and those shown in Table 1 represent for the various ages about the average for all classes of land. The numbers of trees shown for successive ages indicate how tree population gradually decreases, because the more vigorous ones crowd out the others which are unable to keep up in the competition for light and root space.

GROWTH ON CUT-OVER LAND.

Trees of longleaf pine left in logging on the better classes of soils usually show an accelerated rate of growth, sometimes to a very

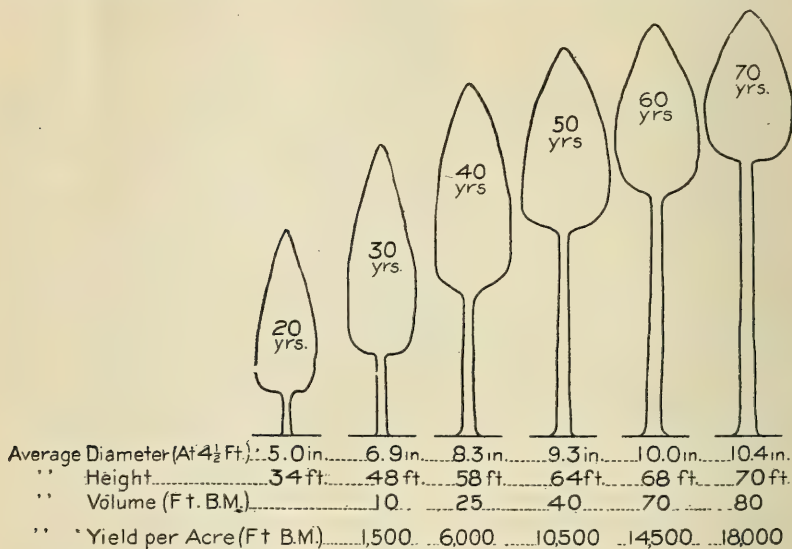


FIG. 3.—Growth and yield of longleaf pine on medium soil.

marked extent. On thin, poor, poorly drained soils, and on very deep, dry, sandy soils an absence of stimulated growth following logging has generally been reported.

In central Louisiana (Winn and La Salle Parishes) accelerated growth in diameters as high as 200 to 300 per cent has been found. Trees, for example, that measured 10 inches in diameter at the time of logging and had grown only 1.6 inches during the preceding 10 years, at the end of 10 years after logging had increased 3 inches in diameter. This represents an actual increase in timber volume of about 200 per cent, or a final volume of three times the former size—a rate which held generally true for trees up to 15 inches in diameter, but fell off considerably for larger trees. With the increase both in size and stumpage value in the 10 years the value of the 15-inch tree went from 23 cents to 72 cents, while the 10-inch tree increased its former value six times.

Another example may be cited. On a tract logged "clean" in 1903, about eight trees per acre were left as culls. They were spike-topped, crooked, and suppressed in growth, and averaged about 8 inches in diameter breast high. Within 2 years these trees had started a rapid growth and for the next 12 years increased at the rate of 1 inch in every 4 years. The average diameter in 1917 was 12 inches. At the time the trees were left they contained 226 board feet per acre and in 1917 a total of 803 board feet per acre, or three and one-half times their former volume—a gain of 250 per cent in less than 15 years. At \$5 per thousand feet, 800 board feet would bring \$4, a sum sufficient to cover, for the entire period of 15 years, the cost of fire protection at 10 cents per year, reckoned at 5 per cent compound interest, and give a return of 5 per cent compounded on an assessed land value of \$2 per acre. Table 2 shows the growth which actually took place on the cull trees during a period of 15 years following logging.

TABLE 2.—Actual growth in volume of cull longleaf pine trees, left in logging, during the 15 years subsequent to lumbering; on loamy sand in the interior coastal plain of central Louisiana.¹

Diameter of trees (breast height) 1902.	Volume of trees (Scribner rule).		Growth in 15 years (1902 to 1917).	
	1902	1917	Volume.	Per cent (based on volume in 1902).
<i>Inches.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Per cent</i>
7	10	80	70	700
8	20	95	75	375
9	32	104	82	256
10	45	134	89	197
11	62	157	95	153
12	83	186	103	124
13	110	223	113	103
14	142	264	122	86
15	185	315	130	70
16	235	371	136	58
17	300	445	145	48
18	375	528	153	41

¹ Measurements by W. W. Ashe, U. S. Forest Service.

GROWTH UNDER FIRE PROTECTION.

Under repeated burning, growth is continually set back and finally most of the saplings are killed. This has, for many years, been occurring over practically the entire South (Pl. VI). The yearly height growth of longleaf-pine saplings from 4 to 12 feet in height (mostly 6 to 8 feet) was ascertained simultaneously on a tract burned over yearly, and on an adjacent tract which, after having been protected for five years, was accidentally burned in February, 1917, and afterwards protected. The average yearly growth in height of 100 saplings, on each of the tracts during a period of

two seasons before and two after the burnings, furnishes good evidence of the effect of protection. (See Table 3.)

Because of the stimulus of increased light and soil moisture, a tree measuring 10.4 inches in diameter at the time of logging grew during the next 18 years to a diameter of 18.2 inches, an average of nearly 1 inch in 2 years. The merchantable length increased from 48 to 56 feet; the merchantable volume from 100 to 326 board feet, an average yearly increase of 13 per cent and a total increase of 226 per cent. The butt log, which at the time of logging would have furnished a 4 by 4 stick, now yielded a 10 by 10 timber. The value of the standing tree at \$1 per thousand was 10 cents when it was left in logging, and in 1920 at \$8 per thousand it was \$2.60. The value of the lumber product of the tree increased from \$1.70 to \$14.75.

TABLE 3.—*Growth in height of longleaf trees from 4 to 12 feet in height, on lands burned yearly and on protected lands. (Berkeley County, S. C.)*

Year.	Yearly growth in height.		
	On land burned over yearly.	On protected or "rough" land (except burned in February).	Growth on burned land on basis of that on unburned land.
	<i>Inches.</i>	<i>Inches.</i>	<i>Per cent.</i>
1915.....	11.8	19.6	60
1916.....	12.9	22.1	58
1917 ¹	15.0	10.2	147
1918.....	12.3	18.1	68
Total ²	52.0	70.0	³ 74

¹ Fire in February.

² Four years.

³ Average.

Thus the two-year average growth of longleaf pine for 1915 and 1916, on the land regularly burned over, was 12.4 inches as compared with 20.3 inches on the unburned land, or a growth on the burned land of only 61 per cent of normal.

Following the accidental fire on the protected land, the growth the following season averaged only 10.2 inches, or about one-half the usual amount under protection; and the following or second



FIG. 1.—The growth of young pine is being observed and measured on the flat “crawfish” lands at the Coast Experiment Station (near Summerville, S. C.), a branch of the Clemson Agricultural College. The trees are numbered, and observations furnish accurate information upon which to base predictions of future growth and forest management. Special measures are taken to protect the land from fires.



FIG. 2.—Following closely behind logging, cull trees, short butts, tops, and branches are being cut up into 5-foot lengths for pulpwood. This is good utilization. Along with this class of material, however, all small pole trees and saplings down to 4 inches in diameter unfortunately are being taken. Some pulp mills in the South are using little else besides second-growth sap pine—a practice that is ruinous to the future forests, and is coming to be realized as such. (Louisiana.)

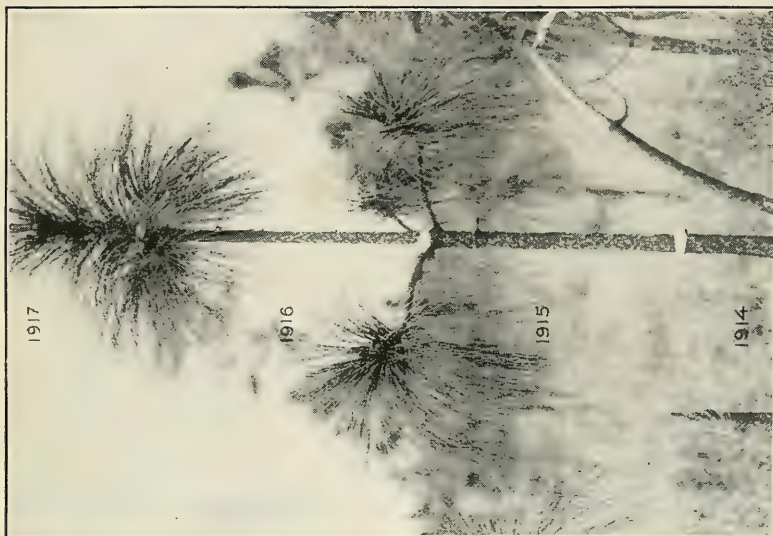


FIG. 2.—Under protection from fire, this longleaf pine grew 12 inches in 1914, 23 inches in 1915, and 28 inches in 1916. However, following a fire in February, 1917, it lost all of its leaves, and during the season had to depend merely upon the single new set of foliage shown, resulting in a growth of only 10 inches during the season. Ends of year's growths marked by strips of white cloth. (Photo taken in early spring of 1918, and the new growth for 1918 is seen in the elongated bud at tip above the leaves.)

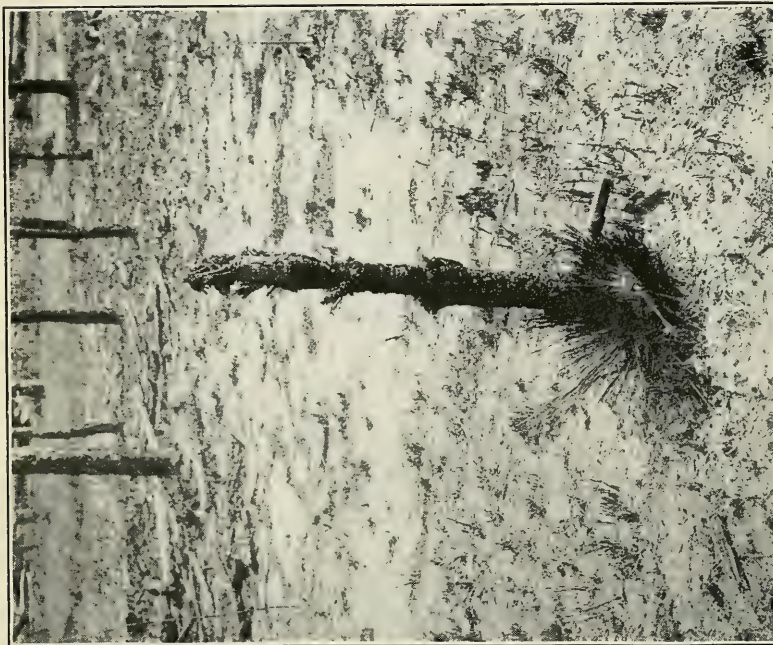


FIG. 1.—Young longleaf pine, 2 feet in height, repeatedly stunted and finally killed to the ground by fires. It has sprouted at the base, but a short time before this picture was taken the sprouts were killed by fire. (Marion County, Fla.)

season after the fire the growth averaged 18.1 inches, still a little below the general average.

PRODUCTION OF TIMBER.

Second-growth longleaf pine is increasingly used for lumber, cross-ties (to be treated), cooperage, boxes, crates, pulp wood, mining timber, and fuel wood. Similar new uses for small-sized timber with wide rings and coarse texture have been successfully found in all the older timber-producing sections of the country.

MEASUREMENTS of adjacent young longleaf stands, one burned and the other unburned for a period of five years, showed an average yearly growth under protection of 18.4 inches, but of only 5.8 inches when burned over every year.

A tract of young longleaf saplings, under observation at Urania, La., after being burned over yearly for five years, contained longleaf saplings mostly up to 1 foot and none over 2.8 feet in height, while in a similar tract protected against fires one-sixth of the trees were over 2 feet and others ranged up to 7 feet in height. The two tracts originally contained approximately the same number of longleaf seedlings and both had been continuously protected against hogs.

The wood of longleaf pine is classed as heavy, hard, and strong. It has been for many years the standard of the southern yellow pines, and by far the leading wood of all southern species in point of amount of production and total value. This applies, of course, mainly to old-growth timber. Second-growth longleaf timber has wider annual rings and contains a higher percentage of sapwood.

The amounts of various products referred to in the following tables and discussion are based upon measurements of sample areas selected as being representative of the best or ideal condition in respect to the density or number of trees per acre. Such well-stocked stands have enough trees so that all the available space and soil moisture are fully utilized. *Fully stocked stands do not occur continuously over large areas, but are confined generally to tracts containing at most only a few acres, such as old fields or the paths of tropical hurricanes. The*

figures of amounts per acre are consequently much higher than those that would result from the cutting of ordinary stands. In the use of such ideal tables there is always great danger of overestimating the amount of timber that is produced and may be cut from average stands as they are commonly found.

CROSSTIES AND CORDWOOD PRODUCTION.

The approximate numbers of crossties and cords of wood (with the bark and without the bark) produced in well-stocked stands at different ages are shown in Table 4. These figures should be considered as only approximate, since various factors enter in to determine the rate of growth and production of merchantable timber. Three qualities of situation are shown under the headings of good, average, and poor land. The yields are based upon the number and sizes of trees as counted and measured in stands and upon the computed number of ties and cords that can be cut from trees of different sizes; the figures do not represent amounts actually cut.

The information contained in Tables 5 and 6 will be found useful in calculating the numbers and grades of ties that can be obtained from trees of different sizes. The sizes of the standard grades of ties are: No. 1, 6 by 6 inches; No. 2, 6 by 7 inches; No. 3, 6 by 8 inches; No. 4, 7 by 8 inches; No. 5, 7 by 9 inches. The standard lengths are 8 and 8½ feet. Table 6 shows the number of ties by grades that can be cut from trees of different sizes, no allowance being made for defects. For example, trees measuring 15 inches in diameter at breast height and 60 feet in height will, on the average, cut out three grade No. 2 ties, one grade No. 4 tie, and one grade No. 5 tie. Table 5 gives the total number of ties without specifying the grades. Copies of specifications for ties may be secured from the local railroad agent or can be found in Farmers' Bulletin 1210, Measuring and Marketing Farm Timber.

TABLE 4.—*Crossties and cordwood (pulpwood or fuelwood) produced per acre by well-stocked, even-aged stands of longleaf pine at different ages. (Approximate.)*

Age of stand.	Crossties (No. 3, 6 in. by 8 in. by 8 ft.).			Cordwood.					
				Wood with bark (fuel wood, etc.).			Peeled wood (pulp wood, etc.).		
	Better land.	Medium land.	Poorer land.	Better land.	Medium land.	Poorer land.	Better land.	Medium land.	Poorer land.
Years.	Ties.	Ties.	Ties.	Cords.	Cords.	Cords.	Cords.	Cords.	Cords.
20	230	30	50	24	14	3	19	10	2
30	440	245	160	49	29	8	39	21	6
40	610	355	270	61	39	17	51	31	13
50	750	510	370	70	48	26	59	39	20
60	870	620		78	55	33	66	45	26
70				84	62	40	72	51	31

TABLE 5.—*Number of crossties that can be cut from longleaf pine trees of different diameters and heights.*

[For detailed information by grades of ties, see Table 4.]

Diameter of tree. ¹	Height of tree in feet.					
	40	50	60	70	80	90
Total number of ties per tree.						
Inches.						
10			1	1	2	
11	1	2	2	2	2 4	
12	2	2	3	3	2 5	
13			3	4	2 6	5
14			4	5	2 6	6
15			5	6	2 6	7
16				6	8	7
17				8	9	8
18				9	10	9
19				10	11	10
20				11	11	11

¹ All diameters measured at breastheight, or 4½ feet above the ground, and outside bark.

² See Table 4, which shows the way the ties were worked up into ties of different grades.

Large amounts of longleaf pine are used for pulpwood by the pulp and paper plants located in the range of the species (Pl. V). Such plants are located at Roanoke Rapids, N. C., Savannah, Ga., Bogalusa, La., Moss Point, Miss., and Orange, Tex. The sulphate process of manufacture is used, and a standard cord of air-dry longleaf pine, containing about 100 cubic feet of solid wood and weighing about 4,200 pounds when air-dry, will produce about 1,600 pounds of dry pulp. The "green" weight of wood as ordinarily handled is variable, depending upon the weather and the time elapsed since the felling of the tree. The southern pine region offers a promising field for the future development of the paper business, particularly for the grade of "kraft," or heavy wrapping paper, for which the wood of the yellow pines is well adapted. Recent tests, however, made at the Forest Products Laboratory have shown the possibility, if proper cooking and bleaching processes are employed, of using the southern pines for the production of high-grade book and magazine paper. This kind of paper requires a long-fibered wood, such as that of the pines, and a short-fibered wood, such as that of the red gum. Crossties from farm timber lands constitute a product of much commercial value. Slack time during the cool season may often be profitably employed in getting out ties. In the winter of 1920-21 the cutting of crossties practically effected the financial salvation of many farmers in various portions of the South. Sap-pine ties, when treated, show good lasting qualities and are being used more and more as heart pine becomes scarcer and more valuable. As young timber grows, it requires more space for proper development, and the thinnings (see under "Cutting") required in well-stocked stands, at intervals of very 5 to 10 years, may often be made to yield good money in crossties or pulpwood.

SAW-TIMBER PRODUCTION.

Information regarding the approximate amount of saw timber contained in individual trees of different sizes is sometimes wanted. The amounts shown in Table 7 are based upon the measurement of 438 longleaf pine trees in central Alabama, taking the logs above a 1-foot stump and down to a top diameter of 6 inches. Table 8 shows the amount of lumber in logs from different parts of turpentine and unturpentine trees.

TABLE 6.—*Number of crossties by grades that can be cut from longleaf pine trees of different diameters and heights.*^a

Diameter of tree (breast high) outside bark.	Height of tree in feet.						
	40	50	60	70	80	90	100
<i>Inches.</i>							
10			1 ¹	1 ¹	2 ¹		
11	1 ²	1 ¹ 1 ²	1 ¹ 1 ²	1 ¹ 1 ²	2 ¹ 2 ²		
12	1 ² 1 ³	1 ¹ 1 ³	1 ¹ 1 ² 1 ³	1 ¹ 1 ² 1 ³	1 ¹ 2 ² 1 ³ 1 ⁴	2 ¹ 1 ² 1 ³ 1 ⁴	
13			1 ² 1 ³ 1 ⁴	1 ¹ 2 ³ 1 ⁴	1 ¹ 1 ² 2 ³ 1 ⁴ 1 ⁵	1 ¹ 1 ² 2 ³ 1 ⁴ 1 ⁵	
14			1 ¹ 1 ³ 1 ⁴ 1 ⁵	1 ¹ 1 ³ 1 ⁴ 2 ⁵	1 ¹ 1 ³ 2 ⁴ 2 ⁵	1 ¹ 1 ² 1 ³ 1 ⁴ 3 ⁵	
15			3 ² 1 ⁴ 1 ⁵	1 ¹ 1 ² 1 ⁴ 3 ⁵	1 ² 1 ³ 4 ⁵	1 ¹ 1 ³ 1 ⁴ 4 ⁵	1 ¹ 1 ² 1 ³ 1 ⁴ 4 ⁵
16			3 ³ 2 ⁵	1 ¹ 1 ³ 4 ⁵	1 ¹ 2 ² 1 ³ 1 ⁴ 3 ⁵	1 ¹ 3 ² 1 ⁴ 4 ⁵	1 ¹ 3 ² 1 ³ 1 ⁴ 4 ⁵
17				3 ² 2 ³ 1 ⁴ 2 ⁵	1 ¹ 2 ² 3 ³ 3 ⁵	1 ¹ 2 ³ 3 ⁴ 4 ⁵	5 ² 3 ³ 1 ⁴ 3 ⁵
18				2 ² 5 ³ 2 ⁵	3 ² 4 ³ 1 ⁴ 2 ⁵	1 ² 6 ³ 1 ⁴ 3 ⁵	3 ² 6 ³ 1 ⁴ 3 ⁵
19				2 ² 4 ³ 3 ⁴ 1 ⁵	2 ² 5 ³ 4 ⁵	7 ³ 5 ⁵	2 ² 7 ³ 1 ⁴ 4 ⁵
20				1 ¹ 4 ³ 2 ⁴ 4 ⁵	5 ³ 2 ⁴ 4 ⁵	7 ³ 1 ⁴ 6 ⁵	2 ² 5 ³ 2 ⁴ 6 ⁵

^a The grade is indicated by the smaller numeral shown above and to the right of the numeral giving the number of crossties of the specified grade. For example: 1² means one No. 2 crosstie. The scale is for straight and sound trees, no allowance being made for defect.

TABLE 7.—*Contents in board feet of longleaf pine trees of different diameters and merchantable lengths.*

[Stump height, 1 foot. Diameter (inside bark) of top, 6 inches. Scaled by Scribner Decimal C rule.]

Diam-eter of tree, breast high.	Number of 16-foot logs in tree.										
	1	1½	2	2½	3	3½	4	4½	5	5½	6
	Volume—Board feet.										
<i>Inches.</i>											
8	16	31	46								
9	17	32	47	62							
10	18	34	50	67	84						
11	20	37	54	74	94	110					
12	21	41	60	83	110	130	160				
13	22	46	67	95	120	150	180	210			
14	24	52	77	110	140	170	200	230	250		
15		58	90	130	160	200	230	260	290	320	
16		64	100	140	180	220	260	300	330	370	400
17			110	150	200	250	290	340	370	410	450
18			120	170	230	280	330	380	420	460	500
19			140	190	250	310	360	420	470	520	560
20			150	210	280	340	400	470	530	580	630
21				230	300	380	450	520	590	650	710
22				250	330	410	490	570	650	720	790
23				270	360	450	540	630	720	800	870
24				290	390	490	590	690	790	880	960

TABLE 8.—Amount of lumber actually sawed out of 16-foot longleaf pine logs of different sizes in band sawmill (Louisiana) and comparison with the Doyle-Scribner scale.

Top diam- eter of log.	Butt logs.		Logs (taken above the butt cut). ¹		Doyle rule.
	Untur- pented.	Turpen- tined (boxing), 4 years.	Rough logs.	Smooth logs. ²	
Board feet.					
<i>Inches.</i>					
6	18	-----	20	16	4
7	27	-----	29	24	9
8	38	32	41	34	16
9	51	42	55	47	25
10	65	53	72	62	36
11	81	67	90	79	49
12	99	81	110	98	64
13	118	96	132	120	81
14	139	114	156	145	100
15	163	131	182	172	121
16	189	151	210	202	144
17	216	-----	240	234	169
18	245	-----	270	267	196
19	275	-----	306	304	225
20	308	-----	-----	344	256
21	342	-----	-----	387	289
22	377	-----	-----	432	324

¹ The greater cut above the butt logs is accounted for by the fact that there was less defect.

² The smaller cut than that shown under the heading "rough" logs is due to an increased product in the form of laths, etc.

In considering the amount of saw timber per acre yielded by longleaf pine, it should be borne in mind that the species belongs essentially to the poorer classes of land, large parts of which are either flat and poorly drained or dry and very sandy. In comparison, both slash and loblolly pines occupy the more fertile, loamy, and humus soil. The figures of saw-timber yields refer to what would commonly be considered as very dense stands, which produce long, clear trunks, yielding clear, high-grade material, but of relatively small diameters for specified ages (Pl. I). Had there been a considerably smaller number of trees per acre than that shown in Table 1, the trees would earlier have reached merchantable saw-timber sizes, and, therefore, would have shown larger amounts per acre, at the ages, say, of 30 to 50 years. Denser stands, however, although slower in growth, give at a little later age a higher total production of timber.

Table 9 shows for different ages of stand and various kinds of land the approximate total yield of saw timber per acre. The market is accepting yellow pine lumber of poorer grades. This change has been rapid since the rise of the extra demand for lumber in about 1917. As a result, information regarding the actual cut of lumber per acre from young stands is frequently desired. The amount shown under the heading of "mill scale" is that which can

be sawed out by using the tree above a 1-foot stump and down to a top diameter of 4.6 inches. It is the form of utilization now general in parts of New England. Another column shows the amount of lumber yielded per acre according to the Doyle log rule—which is in common use in the South—and the difference is striking. Tabulated information of this kind will be found useful in predicting the amount of growth that may be expected to take place during a specified period—5 years or multiples thereof—upon different qualities of situation or classes of land. On medium land, for example, well-stocked longleaf stands at 40 years of age have been found containing an average of 6,200 board feet, and these may be expected to grow 4,200 board feet during the next 10 years, at which time they will contain a total of about 10,400 feet. On good land, or favorable situations, measured 40-year-old stands, well stocked with trees, have contained an average of about 11,000 board feet, increasing during the next 10 years by about 5,200 board feet, to a total of 16,200 feet at 50 years of age. The caution is here repeated that these are fully stocked stands and very much better than the average (Pl. VII). The degree of stocking, or the amount of unused space in the stand, should be taken fully into account in estimating any piece of timber.

TABLE 9.—*Amount of saw timber in board feet grown in longleaf pine stands that are even aged and well stocked with trees.*

Age of stand.	Mill scale, or actual cut.						Doyle rule.		
	Trees 10 inches and over in diameter.			Trees 8 inches and over in diameter.			Trees 7 inches and over in diameter.		
	Better land.	Medium land.	Poorer land.	Better land.	Medium land.	Poorer land.	Better land.	Medium land.	Poorer land.
<i>Years.</i>									
30	5,900	1,200	-----	10,800	5,700	700	3,500	1,900	300
35	8,500	3,800	-----	14,200	8,200	2,200	4,800	2,900	1,000
40	11,000	6,200	1,500	17,100	10,400	3,800	6,200	4,000	1,700
45	13,600	8,400	3,100	19,600	12,600	5,300	7,600	5,000	2,500
50	16,200	10,400	4,600	21,800	14,400	6,900	9,000	6,100	3,200
55	18,800	12,400	6,100	23,700	16,000	8,200	10,300	7,200	4,000
60	21,400	14,400	7,500	25,300	17,400	9,500	11,600	8,200	4,700
65	23,700	16,200	8,800	26,900	18,800	10,700	12,900	9,200	5,500
70	25,800	17,900	10,000	28,900	20,200	11,900	14,200	10,200	6,200

The final yields here shown, it should be noted, are the full contents of the stand at the assigned ages and do not include timber that may have been produced previously, or the intermediate yield, often a very considerable amount. This is the product of any thinings that may have been made (see under "Cutting") and of the timber that has died out during the life of the stand. With advance in the age and size of the trees there comes a natural reduction in the number of trees by the weaker giving way. The process may

be observed in any well-stocked stand in which are found dominant trees, others that are barely living, and still others that have died for lack of overhead light, soil moisture, or root space. If these trees are cut and utilized, the total yield of the stand is considerably increased, and the stand is made more profitable.

The following facts concerning a few of the stands actually measured (see Table 10) will serve as illustrations of what may be expected in the way of yields from well-stocked longleaf stands, commonly considered locally as "dense" stands:

1. A 23-year-old stand, consisting of 210 trees per acre averaging 8.1 inches in diameter and 76 feet in height, contained 23 cords of wood (with the bark) or 17 cords of peeled wood. If all trees measuring 10 inches and over in diameter were cut, the stand would saw out about 2,850 board feet; or if all trees 8 inches and over were cut, it would produce 4,984 feet. By the Doyle log rule, however, all trees measuring 7 inches and over in diameter scaled only 1,430, or less than one-third of what might actually be sawed.²

2. A 25-year-old stand, with 560 trees per acre averaging 29 feet in height and 4.2 inches in diameter, contained 10 cords of wood with the bark on or 7 cords of peeled wood. The stand had no trees as large as 10 inches in diameter, but contained about 700 board feet of timber in trees 8 inches and over in diameter. If the logs in the trees measuring 7 inches and over were scaled by the Doyle rule, there would be only 160 board feet per acre.

3. A 25-year-old stand, containing 279 trees which averaged 54 feet in height and 7.6 inches in diameter, contained 30 cords with bark, or 23 cords of peeled wood. It amounted to 3,579 feet, if it was closely sawed, and if all trees 10 inches and over were used; or 6,980 feet if all the trees down to and including those 8 inches in diameter were taken. If scaled by the Doyle rule, the stand had 2,157 feet.

4. A 50-year-old stand, which consisted of 304 dominant trees averaging 63 feet in height and 9.2 inches in diameter, contained 55 cords of wood with bark, or 42 cords without bark. It had 8,565 board feet if closely utilized down to and including 10-inch trees, or 14,450 feet if the trees 8 inches in diameter and larger were used. The Doyle rule gave 2,128 board feet.

5. A 70-year-old stand—an average of two stands of the same age (Pl. I)—consisted of 265 trees per acre which averaged 68 feet in height and 11.2 inches in diameter, and contained 58 cords of wood with bark or 46 cords without bark. If scaled by the Doyle rule, all trees 7 inches and up showed 9,600 board feet. If cut closely and actually scaled or measured at the mill, all trees 10 inches and up contained about 18,000 board feet, or all trees 8 inches and up (there were only a few of this class) contained 19,400 board feet.

If the above-described stands are examined, and if reference is made to Tables 1, 4, and 9, it will be noted, for example, that the 23-year-old stand (1) consisted of relatively few trees per acre, but that these averaged large both in diameter and in height. Also, as com-

² By the Doyle rule, small-sized timber usually scales only one-third to two-third of the amount that can actually be cut by careful sawing and close utilization in the log.

TABLE 10.—*Longleaf pine*.—Actual measurements of 32 well-stocked second-growth stands, from 8 to 100 years old, showing average sizes of trees, number of trees, and yields per acre, based on selected portions of 78 well-stocked stands from South Carolina to Texas.

Age.	Trees per acre.		Average height.		Average breast-high diameter.		Total basal area.		Yield per acre.						
	Domi- nant trees.	Total.	Domi- nant trees.	All trees.	Domi- nant trees.	All trees.	Domi- nant trees.	All trees.	Solid measure. ¹		Saw timber.				
									Without bark. ³	Cords.	Doyle scale. ⁴	Scribner scale. ⁵	Trees 5 inches and over.	Trees 8 inches and over.	Trees 10 inches and over.
Years.	Number.	Number.	Feet.	Feet.	Inches.	Inches.	Sq. ft.	Sq. ft.	Cords.	Cords.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
10-12.....	1,610	1,610	12	12	2.2	2.2	44	44	3.1	1.9	.....	.....	.....	.....	.....
10-15.....	1,768	1,768	.....	.....	3.3	3.3	49	49	.....	.....	.....	.....	.....	.....	.....
12-17.....	1,690	1,690	25	20	3.4	2.8	64	72	10.5	7.0	.....	.....	.....	.....	.....
15-17.....	292	292	.....	.....	7.0	7.0	78	78	.....	.....	.....	.....	.....	.....	.....
18.....	1,310	1,310	23	23	3.2	3.2	75	75	11.7	7.9	.....	.....	.....	.....	.....
20.....	640	640	36	36	.....	5.7	114	114	24.0	17.0	.....	.....	.....	.....	.....
22.....	448	448	44	44	.....	6.5	128	128	27.0	20.0	.....	.....	.....	.....	.....
23.....	210	210	53	53	.....	8.1	76	76	23.0	17.0	.....	.....	.....	.....	.....
24.....	304	304	53	53	.....	7.9	104	104	43.0	24.0	.....	.....	.....	.....	.....
24.....	216	216	48	48	.....	7.7	68	68	19.0	14.0	.....	.....	.....	.....	.....
25.....	560	560	29	29	.....	4.2	54	54	10.0	7.0	.....	.....	.....	.....	.....
28.....	279	279	54	54	.....	7.6	90	90	30.0	23.0	.....	.....	.....	.....	.....
28.....	192	192	31	31	.....	4.3	20	20	3.8	2.6	.....	.....	.....	.....	.....
30.....	770	770	43	43	.....	4.5	79	79	22.0	15.5	.....	.....	.....	.....	.....
30.....	330	330	44	44	.....	6.9	87	87	22.0	16.0	.....	.....	.....	.....	.....
33.....	303	303	54	54	.....	7.7	97	97	31.0	23.0	.....	.....	.....	.....	.....
35.....	188	188	58	58	.....	8.6	73	73	26.0	19.0	.....	.....	.....	.....	.....
39.....	268	268	58	58	.....	6.5	53	53	20.0	14.0	.....	.....	.....	.....	.....
39.....	148	148	62	56	.....	7.7	61	61	23.8	17.9	.....	.....	.....	.....	.....
40.....	100	100	67	61	.....	9.1	39	45	17.1	13.2	.....	.....	.....	.....	.....
40.....	619	619	52	45	.....	5.9	102	120	34.9	25.6	.....	.....	.....	.....	.....
40.....	260	260	74	70	.....	8.4	133	148	61.5	46.9	.....	.....	.....	.....	.....
44.....	400	400	64	59	.....	6.8	139	173	60.9	45.2	.....	.....	.....	.....	.....
43-48.....	290	290	62	60	.....	8.5	134	155	56.4	42.7	.....	.....	.....	.....	.....
43-48.....	240	240	71	64	.....	9.0	95	104	43.3	33.5	.....	.....	.....	.....	.....



FIG. 1.—The owner values this old field longleaf pine highly. The trees are mostly 20 to 25 years old, and from 30 to 50 feet in height and 8 to 10 inches in diameter breasthigh—a very rapid growth. It is close to his house and furnishes the farm with poles, fuelwood, and recently small saw timber. Twice a year the pine straw is raked off and in part used for fertilizer on the cotton fields and partly sold in turn for stable bedding, as is extensively done in many parts of the South. A section of one is shown in Figure 2. The stand is very irregular and contains only about one-half the full number of trees. (Florence County, S. C.)



FIG. 2.—Section of representative tree in old field longleaf stand shown in Fig. 1. Twenty to twenty-four year old trees are 50 feet tall and 7 to 10 inches in diameter at breastheight. The section, cut at breastheight, shows 16 annual rings. The effect upon growth of a bad fire 9 years ago will be observed in the ninth ring counting from the outside. (Florence County, S. C.)



Chipping at about the midseason of the second year's working. This represents average good practice, but a single piece of iron is being much used instead of two bent gutters. At the rate of one-half inch at each streak, the face moves up the trunk about 16 inches a year. Including the high face, this permits of 6 to 8 years' working.

50-55	304	376	63	62	9.2	8.6	142	152	55.1	41.8	5,348	13,754	16,000	14,449	8,565
50-55	338	436	64	62	9.6	8.9	170	196	71.4	54.4	7,367	18,235	21,059	19,176	10,676
55		146		74		10.9		95	37.0	30.0	6,265	11,570	12,905	12,542	11,819
60-70	104	145	76	69	11.2	10.0	72	80	34.1	26.7	5,898	10,611	11,803	11,365	10,540
60-70	246	386	77	67	11.3	9.6	171	194	82.5	64.4	13,491	25,491	28,211	27,421	25,632
72	198	278	89	86	11.5	10.6	143	170	84.9	66.5	15,102	27,778	30,136	29,196	26,388
100		94		85		15.0		115	55.0	45.0	14,590	20,078	21,636	21,636	21,526

1 All trees 3 inches and over in diameter breast high.

2 Merchantable volume, including bark.

3 Merchantable volume, stump height 1 foot, top diameter inside bark 1.5 inches.

4 All trees 7 inches and over in diameter breast high; stump height 1 foot, top diameter inside bark 5.5 inches.

5 Five and six inch trees scaled as if cut into flitch, to a top diameter inside bark of 3.5 inches. All other scaled to a top diameter inside bark of 4.5 inches, stump height 1 foot

pared with stands of that age, it contained about the average amount of cordwood but double the average amount of saw-timber. The two 25-year-old stands afford an interesting comparison, showing the effect of the tree density, or number of trees per acre. It will be noted that the first stand (2) contained over twice as many trees per acre as the second (3), and that, as a result, they are very much smaller—29 feet in height as compared with 54 feet, and 4.2 inches in diameter as compared with 7.6 inches, about one-third as much cordwood, and only 700 board feet as compared with 6,980 feet of saw-timber. The two 70-year-old stands (5) show very nearly the general average size of trees both in diameter and in height, and slightly less than the average amount of cordwood and saw-timber.

PRODUCTION OF TURPENTINE AND ROSIN.

The bulk of the turpentine and rosin produced in this country has been obtained from longleaf pine.³ The average yearly production for the 6 years ending in 1919 has been estimated to range between 23,000,000 and 25,000,000 gallons of spirits of turpentine and between 700,000,000 and 820,000,000 pounds of rosin. The center of production has changed, gradually following the timber supplies from the Carolinas to Florida. The industry is extensive in Florida and is developing in Louisiana. Second-growth pine now furnishes most of the yield from South Carolina and Georgia, and smaller amounts from Florida and Alabama.

YIELD OF SECOND-GROWTH STANDS.

Young longleaf pine has been for many years worked for turpentine, and this is often its greatest and sometimes its only value. In this respect extensive abuse of young pine has come to be very general. As long ago as 1900 a considerable amount of the turpentine produced in South Carolina and coastal Georgia was derived from young stands of longleaf and slash pine. Since the common practice has been to work young stands heavily, let them burn freely, and make very little further use of them, the destruction of young longleaf has taken place on an extensive scale. Obviously this in part explains the prevailing absence of second growth.

Only a few preliminary studies have thus far been made in the amount of naval stores produced by second-growth longleaf pine. There is much need for accurate information in regard to the amount of gum yielded by trees of different sizes and ages and by entire stands or various ages and tree densities.

Table 11 gives a rough approximation of the yields per crop and per acre of crude gum, turpentine, and rosin from the first year's

³ The remainder has come from working slash pine, a close associate of longleaf. (See Farmers' Bulletin 1256, Slash Pine.)

working of second-growth, well-stocked longleaf pine stands. Caution is necessary, however, in using the table, since it should be regarded as based upon insufficient data to make it final, but it is probably the best of its kind available. It is not based upon actual yields from whole stands, but has been computed from two sets of independent measurements, one relating to the sizes and numbers of trees per acre of growing longleaf stands (Table 1), and the other relating to the flow of gum from a limited number of trees of specified sizes (see Table 12). On the basis of this information, secured by the Forest Service, U. S. Department of Agriculture, the table was compiled jointly by the State Department of Conservation, New Orleans, La., and the Forest Service. It is included here with the hope that it may be the means of stimulating the collection of further measurements and the acquisition of more complete information. The yield of gum per crop is exceedingly variable, as is well known among operators, depending upon the locality and region (extending from North Carolina to Texas), the season, class of labor, and indirectly the market conditions. Hence, any figures of yield should be used with discretion.

TABLE 11.—*Computed production of gum, turpentine, and rosin from well-stocked second-growth longleaf pine stands, of various ages (virgin, or first year's working).*¹

Age of stand.	Production per crop.			Production of gum per cup.	Production per acre.		
	Gum.	Turpentine. ²	Rosin. ²		Gum.	Turpentine. ²	Rosin. ²
Years.	Pounds.	Barrels (50 gals.).	Barrels (500 lbs.).	Pounds.	Pounds.	Gallons.	Barrels (500 lbs.).
20	37,000	18.5	61	3.7	186	4.6	0.3
30	53,000	26.5	88	5.3	1,122	28.0	1.9
40	68,000	34.0	113	6.8	2,190	54.7	3.7
50	74,000	37.0	123	7.4	2,760	69.0	4.6

Trees per acre in stand (all sizes).	Trees cupped per acre (grouped by diameter sizes). ³							Cups per acre.	
	Diameter of trees— <i>inches</i> .								Total.
	7	8	9	10	11	12	13		
150	50							50	50
355	70	90	50					210	210
308	38	43	50	45	45			241	321
280	33	35	40	65	50	25	15	250	371

¹ This table is computed from two different sets of measurements and is not based upon actual measured yields of whole stands. The working of small trees and young stands is not good practice except where trees are to be removed in thinnings or the land to be cleared for other uses.

² Production of turpentine and rosin calculated on the basis of 100 pounds of gum yielding 2½ gallons of turpentine (one-twentieth barrel) and 83 pounds of rosin (one-sixth of a 500-pound barrel).

³ One cup hung on each tree measuring 7 to 9 inches, inclusive, in diameter; two cups hung on about one-half of the 10-inch trees and on all trees measuring 11 inches and over.

⁴ In the 40-year-old stand, 35 of the total 65 trees were 2-cup trees; in the 50-year-old stand, 25 of the 41 trees; and in both cases the remainder of the 10-inch class of trees were hung with one cup each.

Table 11 assumes that well-stocked stands are heavily cupped with one cup to every tree measuring 7, 8, or 9 inches in diameter, one cup on about one-half of the 10-inch trees and two on the remainder, and two cups on all trees 11 inches and over. The figures are for the first year's working. At 30 years, for example, the average yield per crop (10,000 cups) is shown to be 53,000 pounds of gum, which makes in turn about 26.5 barrels of spirits of turpentine⁴ and 88 barrels of rosin. This is obtained from 210 cups per acre, each yielding 5.3 pounds of gum during the season. This number of cups was hung on 210 trees out of a total stand of 355 trees per acre. At 40 years, a yield of 34 barrels of turpentine may be expected. The yield per acre at 30 years was 1,122 pounds of gum, producing about 28 gallons of turpentine and 1.9 barrels of rosin. These yields

The production of turpentine and rosin has shown a marked downward trend for some 15 years. This is due chiefly to the exhaustion of virgin timber. The very wasteful and destructive methods generally employed with both old timber and second growth have always meant a total production much below what would be possible under a more conservative system. If the rate of decrease continues, within the next decade or so the United States will lose its commanding position in the world's market and may in time be unable to supply its domestic requirements.

seem to be very fair in comparison with the average of about 40 barrels of spirits per crop yielded by the better class of mature stands under good working in the Gulf region, and an average for all timber of about 20 barrels per crop. The inclusion of small sizes of trees and very close cupping should not be taken as any recommendation for operating such young stands as a general practice. The figures are given as an indication of what might be expected in working thick stands of young timber before thinning or clearing up the land.

On the Florida National Forest the longleaf pine of all ages and sizes, 10 inches and over in diameter, in a certain contract yielded a virgin working of 96,000 pounds of gum per crop, which gave 48 barrels of spirits and 134 barrels of rosin. This was an average yield

⁴ By a coincidence this is the same yield as shown by the 1910 United States census for the average crop in Georgia, where much of the production is from second-growth timber.

of 9.6 pounds per face, of which 8.3 pounds were dip and 1.3 pounds scrape. The timber as a rule is old and very slow growing, but was worked conservatively.

UNPROFITABLE TURPENTINE PRACTICES.⁵

Working small-sized trees.—The figures given in Table 12 refer to young longleaf pine timber in southern Georgia, and show the weight of gum in cups ready for the first dip after six streaks. The trees ranged from 7 to 12 inches in diameter (measured at breast height, or 4½ feet above the ground); each tree was hung with one cup and was being worked for the first year. The production for the season is computed on the assumption that there were six dippings.

TABLE 12.—Yield of gum per cup in the first dip, and computed yield for the season from different-sized trees.

Diameter of tree (breast high).	Yield of gum per cup.		
	Per dip (6 streaks).	Per streak.	Per season, 6 dippings (computed).
<i>Inches.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Pounds.</i>
¹ 7	10.0	1.7	3.7
¹ 8	15.0	2.5	5.7
¹ 9	19.0	3.2	7.1
¹ 10	22.5	3.7	8.5
¹ 11	23.0	3.8	8.7
¹ 12	24.0	4.0	9.0
² 10	36.0	6.0	13.5
² 11	43.0	7.1	16.1
² 12	48.0	8.0	18.0

¹ One-cup trees.

² Two-cup trees.

The most noteworthy point here is that a 7-inch tree yields less than one-half the gum yielded by a 10-inch tree. Of the 10-inch trees those with two cups yielded 60 per cent more gum than those having only one cup; of the 11-inch trees, they yielded 87 per cent more; and of the 12-inch trees, they yielded 100 per cent more. In operations on small timber the expense of cups, hanging, chipping, and dipping is incurred in connection with many trees that yield only about a quart of gum for a full season's working. Even smaller returns than those shown above are not uncommon. In May, 1920, third-year workings of these small sizes were found that yielded at the rate of 1 ounce of gum to each four streaks. The conclusion arrived at from these weighings is that, in general, timber less than 9 inches in

⁵ The discussion is based upon studies and recommendations by Austin Cary, Logging Engineer of the Forest Service. See also "New Method of Turpentine Orchardling," Forest Service Bulletin 40. For sale by Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 10 cents.

diameter at breastheight, or about 10 inches on the stump, yields gum in such small amounts as to be considered below a workable size.

Faces per tree.—Observations on virgin crops indicate that the addition of the second face, when conservatively made and worked on longleaf pine trees from 10 to 12 inches in diameter at breast-height, increases the yield of the tree by about 70 per cent over the yield of one face. However, when trees under 12 to 14 inches in diameter have been worked with a second face their growth has nearly stopped. They have often been found to be in a sickly or dying condition. The more observing and practical operators feel justified for that reason in not permitting a second face on trees less than 15 inches in diameter; but, if a second face is allowed, they require that bars shall measure at least 4 inches across and that at least 40 per cent of the surface or circumference of the tree shall remain uncut.

Heavy chipping.—For conclusive results regarding the effect of heavy and light chipping, reference may be made to the experiments carried on in Florida by Dr. Charles F. Herty and published by the Forest Service⁶ (Pl. VIII). To this may be added some results obtained by the Forest Service on the Florida National Forest near Pensacola. In these workings the trees were conservatively cupped, and chipping was limited to one-half inch in depth and the same in height. Under these conditions the results per crop of 10,000 cups from five successive years' work on a specified body of timber have been as follows: First year, 46 barrels; second year, 40 barrels; third year, 41 barrels; fourth year, 38 barrels; fifth year, 41 barrels.

The average season's production of gum per crop was, therefore, 41 barrels, with a total of 206 barrels. It will be noted that there was a slight alternation in the amounts, with production the third and last years equal to the average for the operation. A significant result was the subsequent death of only 2 per cent of the trees from dry-facing. Private operations in the same locality using the ordinary old-time system commonly lose from 10 to 20 per cent of their timber and the average yield of gum obtained is approximately as follows: First year, 46 barrels; second year, 38 barrels; third year, 25 barrels; average yearly, 36.3 barrels.

This total yield of 109 barrels in three seasons' working with an average yearly production of 36.3 barrels per crop stands in bold contrast to the result of 206 barrels obtained under similar conditions on the National Forest by the use of better methods.

SUGGESTED SYSTEMS OF TURPENTINING.

A method that is now being tried out on the Florida National Forest in fully stocked second-growth stands starts with the gradual

⁶ "Relation of Light Chipping to the Commercial Yield of Naval Stores," by Dr. Charles F. Herty. Forest Service Bulletin 90. For sale by Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 10 cents.

thinning out of the stand by means of periodic turpentining of the trees to be removed in order to develop an open forest of large-topped, vigorous trees capable of being worked for turpentine repeatedly over a period of 30 to 50 years or more.⁷

Beginning when the trees are 25 to 35 years old, the first step is the removal of the least desirable trees from the stand. These trees, perhaps one-third of the total number, are worked for turpentine under such a system of cupping as will give the maximum immediate financial returns to the operator. When the turpentine value of the tree is gone—probably after a working period of five years—they are cut and utilized. Following the working and cutting of the first lot of trees the remaining stand is again gone over at an age of 30 to 40 years, and the largest trees are selected and designated to constitute the final stand. All other trees are marked for immediate and rapid working under the system of cupping used in the first thinning operation. After five or more years of operation these trees are cut and removed from the stand. This leaves the trees of the final stand which are to receive the conservative turpentine management and from which the chief and sustained money yield of the forest is to be expected.

The final stand consists of only the best trees—those stimulated by the previous thinnings to a state of development much in advance of trees of the same age, 35 to 45 years—in unthinned stands. They should be uniformly and widely spaced and stand 50 to 100 trees per acre. The final stand is now ready for systematic working over a period of 35 to 40 years. The trees are worked conservatively, regular intervals of 3 to 5 years being allowed for rest between the successive 7 or 8 year periods of working up a face. As the tree grows and the wounds heal, narrow faces may be worked between the old ones. At the end of the "rotation," when the trees are considered mature, or at an age of about 80 years, they are heavily worked and then cut for lumber or other products.

This system is quite similar to that in use by the French in turpentining their forests of maritime pine.⁸ The results of five years' operation on the Florida National Forest indicate that no great difficulty will be found in applying it generally to second-growth stands in this country.

A modification of the above method, which is believed by some practical operators to be feasible and promising, follows more nearly the prevailing custom of turpentining in that the operation starts when the largest trees in the stand have attained sufficient size for

⁷ Initiated by Mr. I. F. Eldredge, forest inspector, and for about 10 years carried on under his direction. This applies to all of the turpentining operations on the Florida National Forest from 1907 to 1917.

⁸ For brief description of the French method, see Farmers' Bulletin 1256 "Slash Pine."

COMMON PRACTICES IN TURPENTINING.

(Description of Plate IX.)

FIG. 1.—There are 240 trees per acre, of which 184 measure from 7 to 14 inches in diameter at breastheight, and 56, which are suppressed, measure from 4 to 6 inches in diameter. Some 20 trees per acre of turpentine sizes are too nearly dead from fire for cupping, and a good many trees are missing as the result of repeated burnings.

Some of the trees in this working have two faces and leave insufficient width of bars for the trees to function properly. The result is a marked reduction in the total production. If not disastrously burned, the stand will be worked for a third year. If the stand is afforded protection, the one-face and the two-face trees, which have not become dry-faced, and the two-face trees, which have not become dry-faced, after 5 to 10 years of rest and growth can be reworked. If the timber is not to be cut at the end of the first or second working, a more conservative working than here shown would have been advisable.

At 15 cents per cup for turpentine the stand is yielding the owner \$28.80 per acre, and there will be a cut of some 15,000 board feet of lumber. The effect of the fires has been to deplete the stand of almost one-third of the trees which it should contain at the present time. In the picture some effects are clearly apparent. At the age of 45 years, well-stocked longleaf stands should have about 300 trees per acre all of turpentine sizes (Table 1).

On the same scale of working as here operated, these stands should afford about 400 cups per acre. At 15 cents per cup, and counting in the cups which have been lost by fire, the total return for timber rights would have been about \$60, or an average yearly return for the 45-year period of about \$1.35 per acre. The value of 15,000 board feet of second-growth pine, assumed to be \$3 per thousand, would add \$45 and bring the total average gross income up to \$2.35 per acre yearly.

The operation, as it is being carried on, illustrates well the better class of second-growth stands and the way they are being worked. This one is in Baker County, Fla.

FIG. 2.—This stand of longleaf, with a little slash pine mixed, is about the same age and located near the stand shown in figure 1. It, however, was boxed, worked for three seasons, and since then has been allowed to burn over at random. The trees have been badly burned; some are gone "root and branch," leaving holes in the top soil as the only visible mark of where they formerly stood. More than one-half of the trees originally boxed have been killed or destroyed. The remaining portion in 1916 was considered of no value because it was badly burned, insect infested, and decayed. Eight or nine years had elapsed since the timber was worked. The original tree density was very good; now about four trees are left to every ten that were standing when they were boxed and worked. There are now 55 trees per acre measuring 7 inches or over in diameter. The growth of the trees, which came up in an old field, has been rapid, and the stand of relatively high value. The owner received 10 cents a cup, or from 192 cups per acre (an estimated number) \$19.20 per acre, as the return on the timber for the period of 40 years of growth.

Under adequate protection during the 10 years following the first working, if the trees were back-cupped in 1919, and the timber sold at \$3 per thousand feet on the stump, the profits would undoubtedly have been somewhere near four times the amount received. The treatment of this promising stand represents widespread practice, the folly of which is beginning to be widely and fully appreciated. This operation is in Baker County, Fla.



FIG. 1.—A 45-year-old longleaf pine stand in northern Florida being worked for the second season, with 192 cups on 164 trees per acre. (See description on p. 28.)



FIG. 2 The story is told in this picture of the great waste of timber by fire that very commonly is permitted to follow turpentineing. (See description on p. 28.)



FIG. 1.—For the purpose of conserving the yield of gum, this operator is hanging cups on timber that has up to this time been worked by the crude boxing method.



FIG. 2.—Effect of deep chipping on longleaf pine about 50 years old in Clinch County, Ga. In strong winds the leverage is great and the breaking point is mostly at the top of the face. By careless burning a good many of these faces have been deadened. It is known that pine timber may be worked for turpentine if done in suitable manner without causing great injury either to its value for other purposes or to its rate of growth.

working. After being completely worked the trees are cut and removed, giving space for the accelerated growth of the remaining stand. In the working the trees are bled for about 4 years (with a relatively narrow face to a height of 6 feet), followed by a rest for about 3 years. This operation is then repeated twice with a new face each time, representing in all a working period of about 20 years. If the age of the stand at the start was 30 years, it is now 50 years old. The trees are now cut and utilized, and another 20-year working period begun, making use of the larger trees of the remaining stand.

If the yearly burnings in connection with the turpentineing destroys most of the young growth which starts, as seems likely, in order to secure a satisfactory reforestation of the tract, it may be necessary, in the case of either method of turpentineing, to secure forest regeneration by the artificial means of seed sowing or by planting nursery-grown seedlings.

Operating old-growth timber on the Florida National Forest.—The regulations for turpentine operations on Government-owned timber on the Florida National Forest will afford suggestions to private owners desiring to work or lease their timber, under methods of operation that aim to reduce the injury and waste and maintain the production of turpentine over a maximum period of years. The enforcement of these requirements has been no obstacle to successful forest management, but rather has proved to be a great help. Competition for turpentine rights is keen among operators, and in 1919 the bids reached the high mark of \$25.70 per 100 cups.

Close observation and study of the best practice of turpentineing has resulted in the regulation of 1 cup on trees measuring from 10 to 15 inches, inclusive, in diameter; 2 cups on trees 16 to 24 inches; and not more than 3 cups on any tree. The location of the Forest in western Florida is in a region of deep, dry, sandy soil, where only longleaf pine and southern blackjack oak are able to maintain an existence and where the pine is mostly mature or slow growing.

The timber, however, is worked for about 14 years out of a total of 15 to 17 years. The procedure normally is about as follows, subject to minor variations depending upon conditions: Virgin crop worked for 3 years, high-face 4 years (sometimes 3); a rest period usually of 3 years (minimum of one year); back-cupping carried on for 3 years, and high-face back-cutting for 3 or 4 years. The first working is sold, or if desired, the combined first and second workings together. After the rest interval the same practice of selling the rights is used in the back cuppings. The plan is to sell the timber at the expiration of the working, which will be completed on a certain tract in about 5 years more, the present season being the eleventh since turpentine operations were begun.

An idea of the conditions to which the buyers of turpentine rights on the National Forest subscribe may be had from the following form. The bold-face type indicates the portions of the agreement that are filled in separately in each case, and the figures used represent about average conditions:

UNITED STATES DEPARTMENT OF AGRICULTURE.

FOREST SERVICE.

NAVAL STORES AGREEMENT.

*We, James F. Elder and Wm. H. Johnson, partners, doing business under the firm name and style of Elder and Johnson, of Gracewood, State of Florida, hereby agree to work for naval stores certain timber in the Florida National Forest in accordance with our bid submitted in pursuance of a notice inviting bids therefor, duly given by publication. Said timber is all the **longleaf pine** timber not excepted under the terms of this agreement located on an area of about **640** acres to be definitely designated by a Forest officer before cupping begins in **Sec. 14, T. 1 S., R. 26 W. Principal meridian**, within the **Florida** National Forest, upon which area it is estimated that **10,000** cups, more or less, may be placed. In consideration of the granting of this privilege to **us** we do hereby promise to pay to the **District Fiscal Agent (Washington, D. C.)** or such other depository or officer as shall hereafter be designated, to be placed to the credit of the United States, the sum of **Twenty-five hundred dollars (\$2,500)**, more or less, as may be determined by actual count at the rate of **Two hundred and fifty dollars (\$250)** per thousand cups **in installments, the first of which shall be in the sum of not less than \$1,000, payable on or before the date of execution of this agreement, the second in the sum of not less than \$800 payable on or before February 1, 1923, and the third in the sum of the balance then remaining due on or before February 1, 1924**, credit being given for the sums, if any, hitherto deposited with the said United States depository or officer in connection with this privilege.*

And *we* further promise and agree to work said timber in strict accordance with the following conditions and all regulations prescribed by the Secretary of Agriculture:

1. Timber on valid claims and all timber under other contract with the Forest Service is exempt from cupping under this agreement.

2. No tree will be cupped, chipped, raked, or worked in any manner until payment has been made in accordance with the terms of this agreement.

3. Title to the product of the timber included in this agreement will remain in the United States until it has been paid for as herein prescribed and removed from the tree.

4. No timber will be cupped except that on the area designated by a Forest officer; and all timber on that area will be cupped except as herein specified.

5. No marked tree and no tree **9** inches or less in diameter at a point **4½** feet above the ground will be cupped; not more than one cup will be placed on trees from **10** inches to **15** inches, inclusive, in diameter; not more than two cups will be placed on trees from **16** inches to **24** inches, inclusive, in diameter, and not more than three cups will be placed on any tree.

6. The depth of streaks will not exceed **1/2 inch**, excluding the bark. The width of the streaks will be so regulated that not more than **1/2 inch** of new wood will be taken from the upper side of each streak. The faces chipped or pulled the first season will not exceed **16** inches in height from the shoulder of the first streak of the season to the shoulder of the last streak of the season, including both. The faces chipped or pulled in subsequent seasons will not exceed **16** inches in height, measured in the same way. A No. 0 or smaller hack or puller will be used for chipping or pulling. Bars or strips of bark not less than 4 inches wide in the narrowest place will be left between faces, and this width shall not be lessened as the faces progress up the tree. Where more than one face is placed on a tree, one bar between them will not exceed 8 inches in width. The first streak at the base of the face will be made at the time the apron or gutter is placed. Not more than one streak will be placed on any face during any week except during June and July, when faces may be double streaked, provided that not more than one-half inch is added to the height of the face during the week. Faces not chipped in accordance with these specifications may be marked out and the cups removed by the Forest officer.

7. A cupping system satisfactory to the Forest Supervisor will be used, and the cups and aprons or gutters will be so placed that the shoulders of the first streak will be not more than **10** inches distant from the bottom of the cup, and the cups first placed will be as near the ground as possible. No wood will be exposed on any tree by removing the bark below the gutter or aprons.

8. No unnecessary damage will be done to cupped trees, marked trees, or to trees below the diameter limit. Trees that are badly damaged during the life of this agreement, when such damage is due to carelessness or negligence, shall be paid for at the rate of \$5 per thousand feet board measure, full scale. Trees split or windthrown because of deep incisions for raised tins will be considered as being damaged unnecessarily. The Forest Supervisor shall decide as to the presence and extent of damage.

9. No cups will be placed later than **April 1, 1922**, without written permission from the Forest Supervisor, and all timber embraced in this agreement will be cupped before said date. The cupping will proceed with all reasonable speed.

10. Unless extension of time is granted, all timber will be chipped, dipped, and scraped, the product and all cups, aprons, gutters, and nails removed, and each cupped tree thoroughly raked to the satisfaction of the Forest officer not later than **December 31, 1924**. Tins will be pulled out, not chopped out.

11. No fires will be set to the timber, underbrush, or grass on the area covered by this agreement without the written permission of the authorized Forest officer, and during the time that this agreement remains in force *we* will, independently, do all in *our* power to prevent and suppress unauthorized forest fires on the said area and in its vicinity, and will require *our* employees and contractors to do likewise. *We* hereby agree, unless prevented by circumstances over which *we* have no control, to place *our* employees, contractors, and employees of contractors at the disposal of any authorized Forest officer for the purpose of fighting forest fires, with the understanding that unless the fire-fighting services are rendered on the area embraced in this agreement or on adjacent areas * * * *we* will be paid for such services at rates to be determined by the Forest officer in charge, which rates shall not be less than the current rates of pay prevailing in the said National Forest for services of a similar character: *Provided*, That the maximum expenditure for fire fighting without remuneration in any one calendar year, at rates of pay determined as above, will not exceed \$50; and further provided, That if *we*, *our* employees, contractors, or employees of contractors are directly or indirectly responsible for the origin of the fire, *we* will not be paid for services so rendered, nor will the cost of such services be included in determining said maximum expenditure for any calendar year.

It is further agreed that except in serious emergencies as determined by the Forest Supervisor *we* will not be required to furnish more than 4 men for fighting fires outside of the area above specified, and that any employees furnished will be relieved from fire fighting on such outside areas as soon as it is practicable for the Forest Supervisor to obtain other labor adequate for the protection of the National Forest.

12. All cupped trees will be raked in a workmanlike manner for the space of 2½ feet around each tree during December of each year of the life of this agreement; and, if required by the Forest officer in charge, a fire line not less than 3 feet wide in the narrowest place shall be hoed or plowed around the area covered by this agreement in such a manner as to completely isolate it from adjoining lands. Natural firebreaks such as creeks, swamps, roads, etc., may be utilized with the consent of the Forest officer in charge. These, fire lines must be made and receive the approval of the Forest officer in charge before any cups are placed the first year or new streaks made at the beginning of each subsequent year.

13. Cabins, shelter camps, telephone lines, and other improvements necessary in working the timber covered by this agreement will be constructed on National Forest land only under special-use permit.

14. If requested by the Forest Supervisor, *we* also agree to keep an accurate count and record of the number of barrels of gum and pounds of scrape obtained from the area covered by this agreement and to report the same upon request.

15. The United States reserves the right to sell or otherwise dispose of and remove or have removed all dead timber and uncupped living timber from the area covered by, and during the life of, this agreement: *Provided*, That the removal of such material will not, in the judgment of the Forest officer, interfere with the operations of the purchaser.

16. If during the life of this agreement cups are raised, the nails which had supported them and the gutters shall be removed within thirty days after the raising of the cups.

17. If during the life of this agreement cups and tins are placed on trees at any point other than at the base where they are first placed, a two-piece saw-tooth apron shall be used. In placing these aprons a straight edged driving blade shall be used and an incision made on each side of the face, which incision shall not exceed one-quarter (¼) of an inch in depth.

If desirable in order to allow cups to fit better, narrow chips, not more than ½ inch thick may be removed from the ridge in the center of the faces.

18. Complaints by the purchaser, arising from any action taken by a Forest officer under the terms of this agreement, will not be considered unless made in writing to the Forest Supervisor having jurisdiction, within thirty (30) days of the alleged unsatisfactory action.

The decision of the Secretary of Agriculture will be final in the interpretation of the regulations and provisions governing the sale, cupping, and removal of the product covered by this agreement.

19. All operations on the area may be suspended by the Forest officer in charge if the conditions and requirements contained in this agreement are disregarded, and failure to comply with any one of said conditions and requirements, if persisted in, will be sufficient cause for the termination of this agreement and the cancellation of all permits for other uses of the National Forest incident thereto: *Provided*, That the Forester may, upon reconsideration of the conditions existing at the date of sale and in accordance with which the terms of this agreement were fixed, and with the consent of the purchaser, terminate this agreement, but in the event of such termination the purchaser shall be liable for any damages sustained by the United States arising from the purchaser's operations hereunder.

20. No Member of, or Delegate to Congress, or Resident Commissioner, after his election or appointment, and either before or after he has qualified, and during his continuance in office, will be admitted to any, here or part of this contract or agreement, or to any benefit to arise thereupon. Nothing, however, herein contained will be construed to extend to any incorporated company, where such contract or agreement

is made for the general benefit of such incorporation or company. (Section 3741, Revised Statutes, and sections 114-116, act of March 4, 1909.)

21. The term "officer in charge," wherever used in this agreement, signifies the officer of the Forest Service who shall be designated by the proper Supervisor or by the District Forester to supervise the timber operations in this sale.

22. This agreement will not be assigned in whole or in part.

23. The conditions of the sale are completely set forth in this agreement, and none of its terms can be varied or modified except in writing by the Forest officer approving the agreement or his successor or superior officer, and in accordance with the regulations of the Secretary of Agriculture. No other Forest officer has been or will be given authority for this purpose.

24. And as a further guarantee of a faithful performance of the conditions of this agreement, *we* deliver herewith a bond in the sum of \$1,000, and do further agree that all moneys paid under this agreement will, upon failure on *our* part to fulfill all and singular the conditions and requirements herein set forth, or made a part hereof, be retained by the United States to be applied as far as may be to the satisfaction of *our* obligations assumed hereunder.

Signed in duplicate this *first* day of *December*, 1921.

Witnesses: (Corporate seal, if corporation.)

John Dorman.

Richard Rowley.

Elder and Johnson.

By James F. Elder,

A Member of Firm.

Approved at *Pensacola, Fla.*, under the above conditions, *December 8*, 1921.

W. F. Hillyer,

Forest Supervisor.

USEFUL EQUIVALENTS IN TURPENTINING.

A few equivalents and values in turpentine operations may be useful. They should be regarded only as approximate because of the variable nature of practically every stage of the industry. Although some of the factors refer only to mature timber, others seem to be equally applicable to second-growth trees, and all pertain to the industry as it is being carried on commercially.

1. The yield per tree of crude gum for one season averages from about 8 to 12 pounds per working cup or face on old-growth trees of average size. Based upon the figures in a following paragraph (4), the average yield per cup for a season is from 1 pint to 1 quart of turpentine and from 4 to 5 pounds of rosin.

2. A crop of 10,000 cups under common practice will generally yield from 30 to 45 barrels of turpentine and from 92 to 130 barrels of rosin (500 pounds each), depending upon the favorableness of the season, the size and vigor of the trees, and the method of working.

3. A gallon of spirits of turpentine weighs about $7\frac{1}{4}$ pounds, and a barrel of turpentine contains about 50 gallons.

4. Crude gum or "dip" may be assumed to contain, in round figures, an average by weight of 20 per cent of turpentine, 15 per cent of water and trash, and 65 per cent of rosin. One barrel of average crude turpentine will yield about 10 to 12 gallons of spirits of turpentine. One hundred pounds of clean gum will yield about $2\frac{1}{2}$ gallons of turpentine and 83 pounds of rosin.

5. The yield of both turpentine and rosin is notably increased by the use of the cup system as compared with the boxing method. The yield of turpentine for two similar crops under investigation for three years was 151 barrels by cupping, and by boxing 118 barrels



FIG. 1.—On one square rod, located in a natural opening in virgin timber and indicated by the four white markers, were 84 longleaf seedlings, or at the rate of 13,440 per acre. When examined in the spring these 3-year-old seedlings were beginning to show new green foliage, following a fire about two months before. (Bogulusa, Washington Parish, La.)



FIG. 2.—About 3,500 longleaf seedlings per acre, 2½ years old, growing under blackjack oak. They came up in a one-year grass cover which has since been protected. (Urania, La Salle Parish, La.)



FIG. 1.—Plenty of seed trees were left—the trees left were considered as culls when lumbered (1902), but unfortunately no protection against annual fires and hogs has been afforded. The result, after 15 years, is the absence of a young forest and the loss of considerable old timber by action of fire, insects, diseases, and wind. This condition apparently has misled many people to believe that longleaf land would never come back to timber.



FIG. 2.—Seed trees and protection on longleaf cut-over lands near-by that shown in Figure 1. The young forest of mixed longleaf and shortleaf pines is growing well and producing from 1 to 2 cords yearly of wood suitable for pulpwood or 300 to 500 board feet of saw timber. The seed trees have been making profitable growth as shown on page 11. More trees were left than necessary for seed, but all were considered culls when logged.

**SEED TREES AND PROTECTION—THE ESSENTIALS FOR KEEP-
ING THE FOREST PRODUCTIVE.**

of spirits of turpentine. (Pl. X.) Both shallow and light chipping, as practiced on the Florida National Forest, are effective in increasing the yield of gum.

6. If the yield for the first year is assumed to be 100 per cent, the yields for the following years in per cents for a number of crops were for turpentine 91.6, 70.6, and 62.2, and for rosin 93.8, 74.4, and 69.7, respectively.

7. If the total yield from three years' operation is assumed to be 100 per cent, turpentine operators count on obtaining about 45 per cent the first year, 35 per cent the second, and 20 per cent the third year.

A publication of the Department of Agriculture entitled "Turpentine, its sources, properties, uses, transportation, and marketing, with recommended specifications" (Agriculture Bulletin 898, 1920), may be obtained upon application to the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 15 cents.

EFFECT OF TURPENTINING TIMBER.

It is generally recognized that turpentinizing longleaf as commonly practiced renders the tree very liable to subsequent attack and injury by insects and various fungi, to being felled by wind (Pl. X), and particularly to severe injury by fires. However, if turpentinizing operations have been carefully conducted by limiting the number of faces per tree and the depth of chipping, and if adequate protection has been given, the amount of timber in any way injuriously affected has been shown to be very small; in one large operation in central Alabama it was only about 1 per cent of the total stand.

On the Florida National Forest a study was made, at the close of the third year of working, of several sections of longleaf pine located on private lands and adjoining portions of the National Forest. There had been a severe drought during the working season immediately preceding, and the casual observation of a marked difference in losses of timber suggested the study. On the timber that had been worked under Government regulations the losses were found to be about 10 per cent of the total volume of timber, whereas on the privately operated timber losses were found ranging from 25 to 60 per cent. Natural causes, such as insects, diseases, winds, and lightning, were found to have produced about 4 per cent of the losses. Thus the result of turpentinizing was, roundly, a loss of 6 per cent on Government-operated timber and from 20 to 55 per cent on private workings.

The mechanical properties of the wood are not affected by turpentinizing operations. It may be of interest to know that as far back as 1895 this subject was studied and it was reported that tests and

examinations permit of the announcement without reserve that the timber of longleaf pine is in no way affected by the tapping for turpentine. It is further pointed out that in this statement the chemical as well as the mechanical properties are considered, and thus all doubt as to the comparative durability of timber from bled and unbled trees is eliminated.

Preliminary studies of the effect of turpentinizing upon second-growth longleaf pine indicate, as a result, some check in the rate of growth for an indefinite period of perhaps two to four years following operations, depending on the severity of the bleeding of the tree. Locally near the face, growth takes place rapidly on account of an apparent effort of the tree to heal the wound, making very favorable conditions of the wood for later working. Additional information on this particular phase of growth is much needed.

CUTTING.

Thrifty, well-stocked stands of longleaf soon become overcrowded, and a great competition arises among the trees, the foliage seeking for light and the roots for soil moisture. This should be closely looked after by the owner. Longleaf does not readily thin itself by the natural dying-out process, but many of the smaller trees may live years in a practically dormant condition. The stronger trees gradually crowd and kill the weaker individuals. If such timber is left unthinned, big losses may be expected in the potential timber-producing power of the stand.

With some kinds of trees and forests it is more profitable if the largest trees are cut and the smaller ones are allowed to grow and take the places of those that have been cut. This system, however, is not generally to be recommended for longleaf pine. The method of cutting believed to be most applicable to longleaf consists in thinning from the bottom upward, that is, in removing first the less thrifty, overtopped, diseased, and unpromising trees. In crowded groups, good-sized trees should sometimes be removed. The cooler part of the year affords the only reason that is safe against dangerous insect menace following cutting operations. (See under "Insects, Disease, and Wind.") Such thinnings should be made as needed, usually at intervals of 5 to 10 years, each helping in the development of the final stand. The purpose of thinning is very much the same as that of the farmer in chopping his cotton or corn, namely, to give the remaining plants proper growing space and to secure the largest amount of the desired product. Trees growing wide apart in understocked stands may not need more than one thinning or they may not need any. If young longleaf stands contain undesirable kinds of trees, such as slow-growing, wide-spreading gums

or oaks, which shade out a lot of pines and promise less valuable timber, these should be cut out much as weeds are eradicated from fields. This process, known as "cleaning," may not be necessary more than once. The last thinning is followed, at a suitable age and development of the trees, by a clean cutting of the stand. The clean-cutting method is recommended for longleaf, because this species grows naturally, and probably best, in pure stands or mixed with small amounts of other pines. Longleaf, apparently, grows fastest into timber when it comes up uniformly over the land and is kept at uniform heights, for it is a species that needs an abundance of light, and hence must not be shaded by taller trees.

The desired number of trees per acre for a given stand is determined largely by the quality of the locality or the favorableness of the situation, and by the size and age of the trees. It is, after all, more a matter of judgment and experience than of rule. (See Table 1.) In the earlier thinnings, when the stand is about 20 years old, sometimes as many as one-fifth to one-third of the trees should be removed. These usually represent, however, less than one-fifth of the total timber volume of the stand.

The final clean cutting of the stand should include provisions for early restocking of the land before oaks and other inferior growth get a footing. A good way to do this is to leave seed trees. These should be the vigorous, full topped, or limby trees, of less value for lumber. In practically all stands they may be found growing alone in openings, and hence are well rooted and wind firm against the storms that may follow the cutting. It is well to spot the trees with white paint before cutting operations are begun, as is being done in some operations in the South. Certain State laws require this, as pointed out under "A seed-tree law." It is sometimes good practice to cut to a diameter limit, as, for example, down to 12 inches. In this way trees below good merchantable size will be left on the ground to aid in reseeding the land and to provide good material for cutting 5 to 10 years later. In logging timber, often no profit but a positive loss is incurred by trying to handle trees too small in size. Good forestry in lumbering operations calls for preserving the young and thrifty trees.

The amount of material secured from the several thinnings required in well-stocked stands up to an age of 50 to 70 years might easily be equivalent to one-third of the total amount yielded at the final cutting of the stand. The value of the timber, of course, would depend upon its location with reference to transportation facilities and upon the competition from outside markets. Wherever possible the trees to be removed in thinnings should first be worked for turpentine, because at times the gum brings more than would be realized

from the later sale of the timber. The progress of good roads is rapid, and it requires only a relatively short sight to anticipate the day when one's young pine will come into its own and have a very real value on the stump. With the higher prices that are being paid for all forest products, including lumber, crossties, poles, piling, fuel wood, paper pulpwood, and turpentine rights, the proper disposal of young timber is well worth looking after and should offer more than pay for the cutting.

REFORESTATION.

One often hears it said that the land will never come back to pine. To a great degree this statement has been justified, and it will be true so long as the prevailing practice continues and the prevailing sentiment maintains that the woods "just will burn and must burn." Getting young longleaf started, however, is not a serious problem. The bulk of the cut-over land has some seed-bearing trees; throughout much of the South there is probably a sufficient number of seed trees. Contrary to the general belief, cut-over longleaf lands have at rather frequent intervals become well stocked with seedling stands, each in turn of relatively short duration, because of agencies mostly of man's making and mostly under his control. Fire and native hogs have been the undoing of young longleaf pine. Reforestation thus becomes largely a matter of educating people as to the destructive nature of fire and hogs and as to methods of providing the necessary protection. The reforestation of lands from which all longleaf trees capable of bearing seed have been removed involves the necessity of starting young growth by artificially sowing seed or by planting small seedlings. Both the natural and artificial methods will be briefly considered.

SEED PRODUCTION AND GERMINATION.

Longleaf trees bear seeds at intervals of two to four years. In stands some seed is borne almost every year. Apparently about every seven years heavy crops of seed are produced generally over the longleaf belt. Such heavy seed years occurred in 1913 and 1920, and a fair crop was borne in 1916. Incidentally, the production of a heavy crop of seed is accompanied by a shrinkage in the flow of gum in turpentine operations. An experienced operator, in charge of one of the largest and most up-to-date turpentine plants in the South, estimated that the shrinkage of crude turpentine production in 1920, coincident with the maturing of the heavy seed crop, amounted to 10 to 15 per cent. of the normal production.

The seeds are relatively large, averaging about 7,500 to the pound, and rich in food materials. The seeds are provided with wings which

usually carry them away from the tree for distances up to once or twice its height, and in strong winds as far as several hundred yards. Compared with the seed of most of the yellow pines, that of the longleaf is heavy and not widely dispersed. A reliable observation was reported in the fall of 1920 of an abundant seeding taking place on the leeward side of old timber at a distance of about one-quarter mile from the margin.

Like all pines longleaf requires two growing seasons to mature its seed. The seed ripens in September and soon falls from the cones. The normal time for germination is probably from two to five weeks after the seed falls, or during October and November. The seed possesses quick germinative energy and has been known to sprout in damp weather while it is in the partially closed cones on cut trees, and frequently while it is in cones lying on the ground. Seed collected in Florida in the fall of 1920 gave a germinative test of 5 per cent in 5 days, 32 per cent in 7 days, 71 per cent in 2 weeks, and 73 per cent in 17 days. Probably about 70 per cent of the seed good or viable is representative for the better grades, and about 50 per cent is the usual average. No other species of pine, so far as known, shows quicker activity in seed germination and the establishment of the seedlings (fig. 4).

SEED-TREE METHOD—NATURE'S WAY.

If proper methods are followed at the time of cutting, and if a few good seed trees are left per acre, not a dollar need be spent for seed to start young longleaf. In order that the seedling may get a good start, it is necessary for the seed to come in contact with or close to mineral soil. In low ground, where the soil cover is very heavy ("rough") and contains more than a year's growth, this is not apt to happen. The necessity then arises of preparing the ground to receive the seed. Observations show that even in deep grass a few seeds fall in openings and germinate successfully. In some cases it may be found advisable, during the winter or early spring before a good seed crop is anticipated, to burn over lands which it is desired to reforest. This will afford a light grass cover which is probably more favorable to successful germination than entirely bare soil, such as the seed would fall upon directly after the burning. Where fires have been of yearly occurrence and in regions of thin grass or other sparse soil cover, such measures will be unnecessary. The preparation of a good seed bed might be tried experimentally by turning in hogs early in the fall of a seed year, but excluding them in time to be sure of a sufficient supply of seed on the area. Natural stands up to 20,000 seedlings per acre in the spring after the heavy seed crop of 1920 were not uncommon on the Florida National Forest. On adjacent lands not under Government ownership and having fewer seed trees, the young forest

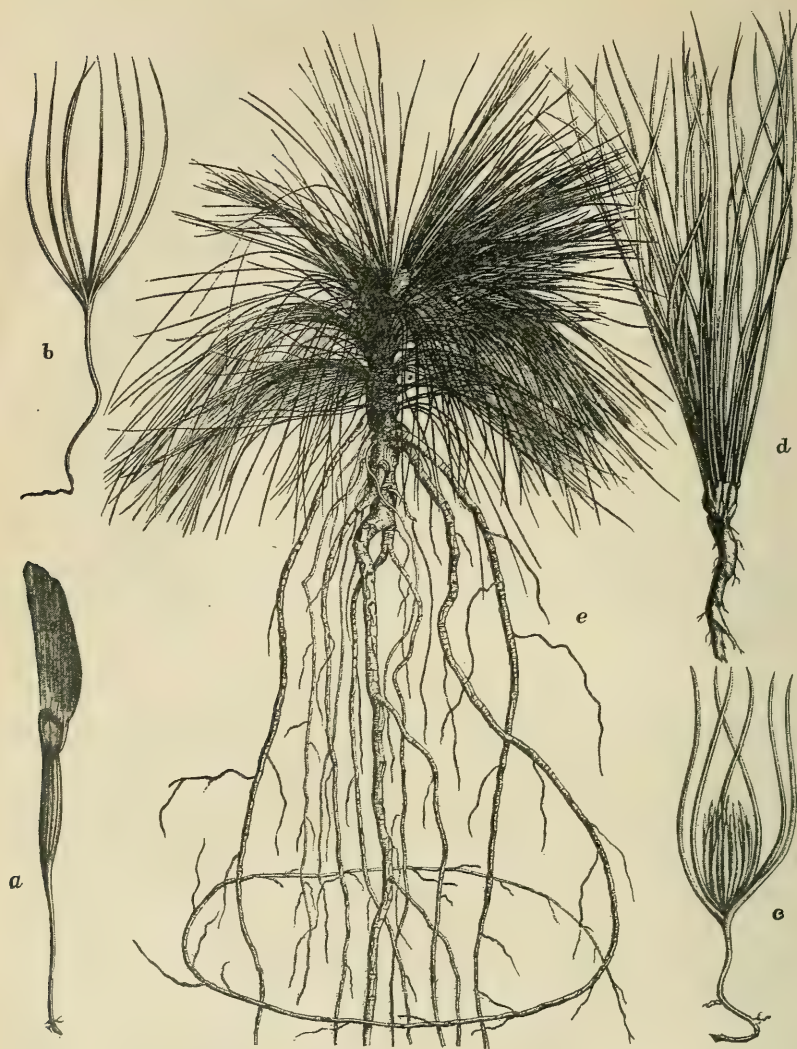


FIG. 4.—Early development of longleaf pine.

a. Seedling in October or November from 2 to 4 weeks after fall of seed.

b. Appearance a few days later, when the empty seed coat has been shed.

c. By January to March the true leaves (in sheaths with 1, 2, or 3 leaves) are expanding as shown.

d. During the first season after germination the plant develops a very short stem, above the taproot, supporting clusters of long true leaves. The early seed leaves, or cotyledons, it will be noted, have been shed.

e. A dense tuft of long, slender, drooping leaves, the whole gradually expanding and massed on a short, stout stem, gives longleaf pine its characteristic appearance during the first 3 to 5 years. It is this mass of green foliage and the so-called "asbestos" bud that enables longleaf to persist through repeated fires. Below is developed the very heavy, long tap root and strong laterals, which in other pines usually accompany saplings 2 to 6 feet in height. (From Forest Service Bulletin 13.)

was on the average only about one-fourth as dense. Stands of 4,000 to 13,000 seedlings per acre (Pl. XI) the second and third years after seeding are not uncommon.

Although good seed years are generally followed by good stands of seedlings, it is not always so. Because of the palatability of the large kernels, great numbers of seeds are known to be destroyed by weevils, birds, mice, rats, squirrels, and razor-back hogs, and prob-

HELP REFOREST THIS TIMBERLAND

Longleaf pine bears seed in quantities only once in every 5 or 7 years.

This is a mast year, and this fall and winter will produce the only seed in quantity that can be expected before 1926 or 1927.

On the seed fall of this season depends in large part the future supply of naval stores and saw timber of this region.

The young pine seedling is quickly and totally destroyed by fire during the first two years of its life.

Nature will do its part by furnishing and sowing a bountiful supply of seed. Will you do your part in helping to prevent forest fires while the seedlings are being established?

Join us in starting a new stand of timber.

U. S. FOREST SERVICE.

Be careful with fire in the woods. If you find a fire burning, put it out if you can; if you need aid, notify the nearest Forest Ranger.

The Government on its National Forests in the South is reforesting its lands by the natural method of leaving seed trees and protecting the young growth from fires.

ably to some extent by cattle, where the seeds collect in wagon ruts and other depressions. It is believed that the practice of shooting hawks and owls has allowed the various rodent pests to multiply greatly. Favorable weather conditions during the first six months or so after the seed falls will greatly increase the number of trees that become established.

The best trees for reseeding the cut-over lands are, all things considered, the younger, full-foliaged, vigorous-growing trees.

These usually have been standing apart and are relatively very wind-firm; in favorable situations they will increase rapidly in size after the logging of the other trees. A woodsman can readily come to recognize such trees, and they should be chosen and marked by paint or other means prior to logging. If all slash is cleared away from the trees, and proper protection from fire is provided, within periods of 5 to 15 years the seed trees should provide ample young growth and be of enough value to pay all costs and a fair rate of interest on the total investment. (Pl. XII.) The probable value of the young pine stand by the twentieth year should be sufficient to offset and justify the whole cost of producing the trees, including the holding of the land. In general, seed trees of

If cut-over lands have been properly logged, and if seed trees have been left in the operation and been given adequate fire protection, the lands will become reforested naturally and the planting of seed will not be necessary.

There are many millions of acres of southern pine lands which have been cut so heavily or burned over so often and so completely that they can not become restocked naturally, and will therefore lie idle unless they are artificially reforested by the sowing of seed or the planting of seedlings.

If these lands were restored to timber production and were given adequate fire protection they would produce yearly from 100 to 400 board feet per acre of longleaf pine.

the right kind should cause no loss but rather prove to be a good investment.

A seed-tree law.—As a step in the development of sound forest principles, the State of Louisiana in 1920 enacted a seed-tree law. It is required that at least one seed tree per acre be left on lands cut by any individual or company, unless such land is agricultural in character and will be used for that purpose. A seed tree has since been defined as a "sound tree of well-developed crown and not less than 8 inches in diameter at 2 feet above the ground." The law covers just about the minimum requirement in this respect. It is better if at least three to five such trees per acre are left. The purpose of the law is to prevent complete denudation of forest land and yet work no hardship upon the owners. Some chance, at least,



FIG. 1.—The simple manner of sowing longleaf pine broadcast as conducted in the fall of 1920 by large holders of cut-over lands in Louisiana. The seed carried in sacks and sown at the rate of 2 to 4 pounds per acre. The cost was \$1.50 for the seed (3 pounds) and 15 cents for the sowing, or a total of \$1.65 per acre. The grass has been previously burned off. Experiments, however, have not yet progressed to a point which warrant definite recommendations regarding the best conditions of grass cover and methods of starting young longleaf forests.



FIG. 2.—A part of the 4,000 pounds of longleaf pine seed collected from the heavy seed crop of 1920 by a large sawmill company in southeastern Louisiana. The seeds were shaken from cones ("burrs"), that had opened on the ground in clear, dry weather, into pans, and brought in and sold by the collectors at 50 cents a pound. The large membranous wings are easily removed from the seed by a rubbing or beating process.



FIG. 2.—This tract of cut-over land in southeastern Texas is the result of a definite plan of the owner to get the land producing timber and grazing. The condition of the forest and range within are shown after about 14 years of protection. A "cull" tree, left in logging about 15 years before, which has since acted as a seed tree, stands near the center. The owner values highly the range for his cattle and hogs and the promising young longleaf forest. (Hardin County, Tex.)

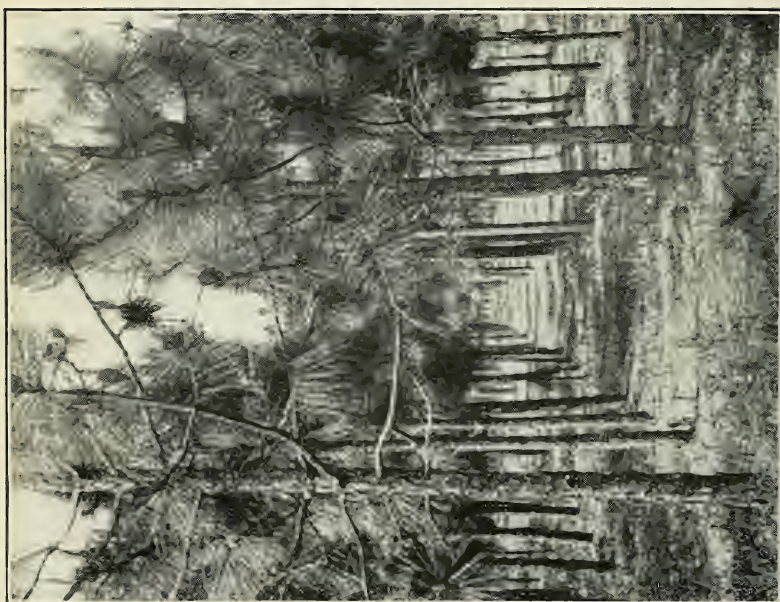


FIG. 1.—A logged pine plantation in southwestern Louisiana, about 14 years old. Small seedlings 3 or 4 years old were dug up in the woods and set out in rows 8 years ago. This planting was made by the head of a big sawmill plant, who doubtless foresaw the time when such seedling would call for pulling the old cut-over lands to work and making them financially productive. (Beauregard Parish, La.)

will be afforded of cut-over lands being reforested naturally instead of remaining idle unless they are restocked by artificial seeding or planting (Pl. II).

Example of leaving seed trees.—On its own initiative a large lumber company in southeastern Louisiana is going further than required by law, and is leaving and protecting practically all small trees. The skidding crews are required to save as many small trees as they can and to throw all slash from the bases of these trees. A considerable space around the trees is raked and the wounds are painted over. In addition to relying on these groups of the smaller trees, single trees of moderate size and heavy tops which stand isolated are being left for seed, wherever needed. These are selected and ringed with paint in advance of cutting or turpentineing.

It is believed that these measures will prove sound from a business standpoint. The plan does not put much value at risk, and the total cost, including the stumpage, is probably 15 to 20 cents per acre. In themselves the seed trees are likely to prove a good investment, on account of their accelerated growth, and in addition there is the enhanced value of the land that contains a good young forest stand. The leaving of very old longleaf trees for seed production has resulted in some losses, because the trees have either died standing or been blown down. Of those that died, some were killed by lightning and some by certain insects⁹ which do extensive injury over much of the South.

SOWING AND PLANTING.

Available information may indicate the best lines to follow in making denuded lands produce an income. Apparently the best time for artificial seed sowing is soon after the seed matures—during October or early November. If sown much later, it probably remains dormant until the coming of warm weather. Meanwhile, the menace is great from the numerous enemies. Hence, if not sown by November, the seed should be put in storage in a cool place until about the time vegetation starts in the spring. The seed is rich in food elements and apparently deteriorates more rapidly than that of some other species of pine. The best method of storing pine seed is to place it in sealed containers after it is thoroughly air dried. Cold storage below freezing has also given fair results. If the seed is to be kept longer than a few months, one of these methods is recommended.

As to the preparation of the soil, plowing and harrowing have given the best results; but this method is obviously impracticable, because of the high cost. The results have generally varied with the degree of preparation of the soil.

⁹ Belonging to the genus *Ips*. Studies have been made by the Bureau of Entomology, U. S. Department of Agriculture, to whom inquiries should be addressed.

The simplest method of sowing is to broadcast the seed over the natural grass land. From 2 to 4 pounds of seed per acre is believed to be about the right amount. After the sowing, if the land is clear enough to permit it, a spike-tooth or spring-tooth harrow should be run over it for the purpose of working the seed down to the soil. In this grass the seed will generally settle in the openings sufficiently to come close to mineral soil, and be afforded partial shade and protection against extremes of heat and moisture. A light ground cover, such as one season's growth of grass, is generally favorable to the establishment of the seedlings. A heavy covering of grass, fine leaves ("straw"), or oak litter, which might not keep the seed from germinating, would, however, prevent many of the seedlings from becoming established. Another method of sowing that has given fair results in loose, "black jack" soil, consists of drilling in the seed with an ordinary corn planter or seed drill. The drill should be low-built and strong, and preferably of the type that passes every seed in plain view of the operator. A bull-tongue or a scraper may be used, depending upon the character of the soil. A quiet, steady animal, needless to say, is desirable, on account of roots and other obstructions. The seed should be barely covered, not in excess of one-quarter of an inch. A modified and usually more expensive method would be to drop and cover about 10 to 15 seed in a prepared "hill" or seed spot, using a hoe or a mattock much as in planting a garden. Several furrows may be run, and the seed may be sown broadcast over the area and brushed or harrowed in.

The aim should be to get trees growing at regular intervals of about 8 to 10 feet, or from 680 to 430 trees per acre. Because of the inevitable loss of some seed and seedlings from various causes, there will be a better chance of a good stand at, say, 10 years of age if more than 680 trees are started. Until further knowledge is available regarding methods of starting young longleaf stands, it will be desirable to make small-scale test sowings under different methods, with such variation as may seem advisable to suit local conditions, in order to determine which is most suitable for more extensive operations.

During the fall of 1920, a large sawmill concern in Louisiana collected about 4,000 pounds of seed of longleaf pine and also some seed of other species. It was obtained in part from dried cones ("burrs") picked from trees felled in logging, but mostly by the cheaper and more satisfactory method of gathering up cones that had opened on the ground after falling, and shaking the seeds out into a pan or tub. Incidentally it may be mentioned that the price paid to the collectors was 50 cents per pound. The seed was sown broadcast, part on plowed strips spaced 8 feet apart, each made up of several furrows and afterwards harrowed to work the seed in, and

part on natural and recently burned-over grass land (Pl. XIII). An average of 2 pounds of seed per acre was used for sowing the furrow strips and 2 to 3 for broadcasting on the grass land. The cost for broadcast sowing was 15 cents per pound and for drilling or harrowing 32 cents an acre. The plowing was done in the late fall by farmers hired after work became slack on the farm. The areas seeded were previously fenced against cattle and hogs, and plans were immediately made to keep fires out thereafter by means of fire lines and other protective measures.

The planting of longleaf seedlings, because of the very large taproot, is likely to be more restricted than that of most other species of pine. The possibilities in this line have not yet been fully tested. Successful experiments were conducted on a limited scale in eastern North Carolina by the Forestry Division of the North Carolina Geological Survey. These consisted in planting (or "transplanting") in the spring 5-month-old seedlings obtained from freshly gathered seed sown in a garden bed the previous October. The soil was shallow, with a firm subsoil, and this produced a taproot not more than 8 inches in length. At the same time, a limited number of 2-year-old seedlings were also planted with very good results. Among the residents of Southern Pines and Pinehurst, in the "sand-hill" region of North Carolina, it has been common practice to dig up volunteer longleaf seedlings from 1 to 4 years old and plant them about town in the winter season, and generally there has been little loss. One such plantation in Louisiana, about 14 years old, is shown in Plate XIV. After the first year or two, it is certain that the degree of care necessary for successfully planting young longleaf seedlings increases greatly, apparently to such a degree as to make operations on a commercial scale impracticable. Up to the present time the evidence points to good success from the spring planting of seedlings 4 to 5 months old, either when grown in prepared soil in garden beds or when dug up in the woods or old fields.

In general, reforestation by the method of planting seedlings should be attempted only in unfavorable situations where such cheaper methods as direct seed sowing have proven unsuccessful. Planting has the advantage of starting the trees in the locations desired, and thus, if successful, of securing an even stand at the outset. Soil preparation may always be expected to result in better growth, at least for a number of years. The degree and kind of soil preparation that can be given will vary widely with conditions. In fairly loose soil, shallow holes dug with a mattock or hoe should be sufficient. Undoubtedly a better method, which should prove practicable in light sandy soils, would be to prepare strips by plowing two or three furrows together, spacing them at desired intervals of say 8 to

10 feet, and planting the seedlings at about the same distance apart. Soil preparation, although helpful at the start, is usually not necessary for the growth of seedlings.

Blackjack oak lands.—The presence of much scrub or blackjack oak on cut-over lands is generally considered to be a great interference with the securing of a good natural reproduction of pine. Much of the oak did not “come in” after logging but was already present as stunted shrubs hardly noticeable at the time of logging. Undoubtedly the oak hinders reproduction by forming a thick layer of leaves which prevents many seeds from reaching the soil. The absence of young-growth pine, however, is often directly traceable to the absence of sufficient seed trees and to repeated fires. This type of oak occurs most commonly on dry ridges where fires are frequent and unusually severe. Young pine which gets a start, therefore, stands small chance of living against such odds, while the oaks sprout and seem to become more dense as a result of the action of the fire. If sufficient seed trees were left in logging, and young growth got started, it is likely that the hot fires would weaken or kill many of the seedlings in the first few years. A good growth of longleaf seedlings and saplings has repeatedly been observed among oak thickets (Pl. XI) in various parts of the South.

It may be found advisable to cut out some of the oak and make openings for the pine to get a start, as has been done by at least one lumber company in Louisiana. Various preparations, or “herbicides”, are on the market for use in killing trees, and the Department of Agriculture, Washington, D. C., upon request furnishes information regarding their preparation and use. In oak thickets where seed trees are present in sufficient numbers, and where no fires have occurred in several years, in order to secure pine reproduction, many people believe that it may be advisable to burn over the land in the winter preceding the fall in which a good seed crop is anticipated. This will allow the seed to reach the soil. Protection against fire should thereafter be afforded. In the absence of good seed trees, at least an average of one to each acre, artificial methods of seed-sowing or the planting of seedlings must, obviously, be employed.

PROTECTION.

PROTECTION AGAINST FIRE.

Every informed and right-thinking person knows that the stopping of forest fires is the first step in the reproduction of forests. Fires in the woods have lost to the South a rich heritage amounting to many hundreds of millions of dollars. If the lumbermen had already cut every stick of the original-growth pine, but, if from the start, fires had been kept down, the South undoubtedly would today



FIG. 1.—After being protected for a period of 5 years, this longleaf pine was defoliated by fire (in February, 1917) up to a height of about 10 feet. The photograph was taken in the following April, when the new leaves were beginning to show.



FIG. 2.—The same stand as above, photographed at the close of the second season of growth (January, 1919). The tree growth was notably checked during the first year (see p. 12), because of the extra drain in completely renewing the foliage. Only the small stunted "runts," resulting from a former period of annual burning, were killed by the fire.



FIG. 1.



FIG. 2.

FIGS. 1 AND 2.—Views taken on opposite sides of a road in Jasper County, S. C. One side is burned over nearly every year, while the other is protected by a near-by farmstead and two roadways; the contrast in development and growth is probably representative for the whole longleaf pine belt. A count in the burned stand revealed the fact that the last fire had killed just one-third of the total number of trees, as shown by the white tags.

EVERY FIRE TAKES ITS TOLL.



FIG. 1.—A splendid start for a profitable piece of longleaf pine timber.



FIG. 2. Under fire protection, young longleaf pine grows rapidly and in a comparatively short time reaches suitable size for turpentine, cross-ties, or pulpwood, and later for sawing into boards or other small dimensions. This stand is from 12 to 15 years old. Many young stands are, however, worked much too young.

RESULTS OF PROTECTION.



FIG. 1.—A small farmer in east Texas ran a hog-proof fence around a piece of some 20 acres of cut-over land near his buildings. He excluded hogs for 6 years and most of the fires for 12 years. The result, in part, is shown in the above view; a full stand of longleaf pines 25 to 35 feet high and 3 to 6 inches in diameter at breastheight. The owner regards the whole thing with much satisfaction, for he has a rich pasture for cattle and hogs and a valuable stand of pine about reaching the size of thinning by turpentining.



FIG. 2.—Part of the same cut-over tract shown above, looking in the opposite direction from the same spot; unprotected from hogs and subject to frequent fires.

be far richer in timber than it is. At best, few fires would probably have occurred, and some probably always will occur. Public sentiment in the South will some day reach the point where fires, so far as humanly possible, will be eliminated; those which do start will be attacked and brought under control, and the great area of natural forest land will be brought into productiveness.

A vast amount of longleaf pine is killed or seriously injured by fire every year. The first-year seedling is very susceptible to fire. The growing sapling is always set back or stunted when robbed of its tuft of foliage, and, as the result of repeated attacks, it weakens and dies. The few saplings that succeed in the struggle and reach pole size are usually worked early for turpentine, and within a period of 5 years thereafter most of them become a complete loss as a result of burning and the subsequent attacks of insects and diseases or of windfall.

The power of longleaf pine to withstand the effect of fire is remarkable. It is very likely that this exceptional adaptation has given the species the popular reputation of being completely immune from fire, and even of "thriving on fires" (Pl. XV). The fact that many longleaf saplings survive an ordinary burning fire is no adequate reason for implying that longleaf is immune and suffers no injury from fire. Every fire, with probably few exceptions, takes its toll in the death of a greater or less number of trees, and in addition causes much injury to practically all the others (Pl. XVI). The degree of injury varies widely with the size of the tree, the amount and dryness of the inflammable material, and velocity of the wind. In this manner promising young stands have been repeatedly wiped out from the same tract of cut-over land. A few stragglers can usually be found, giving a clue to the successive young stands that at various times have provided the land with the making of a forest.

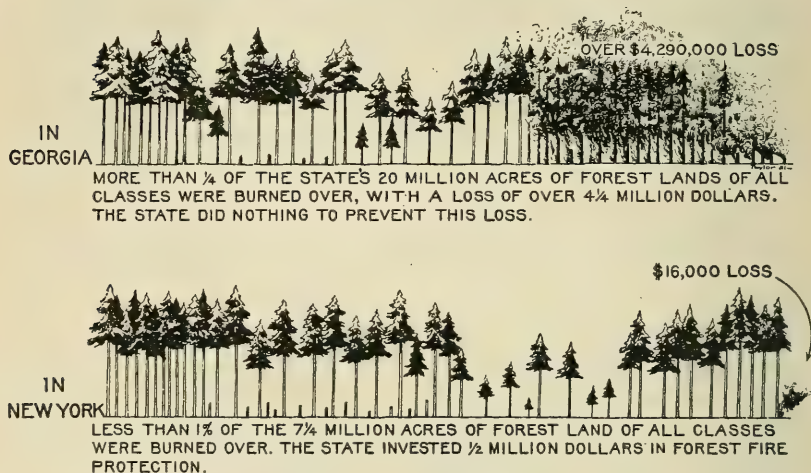
If fire burns underneath 1 or 2 year old seedlings, they are usually killed. A quick grass fire under a stiff breeze, however, passes so rapidly that many 1-year-old seedlings may survive. If fires burn in summer or fall during dry weather, longleaf seedlings up to 8 years old are very apt to be completely wiped out. From about the second year up to the fifth year, or at heights up to about 1 foot, longleaf seedlings appear to be relatively very restant to the effects of fire. For longleaf pine the zone of greatest injury from fire is apparently from 1 to 5 feet above the ground, where the heat blanket is most intense. This corresponds to the ages of approximately 5 to 8 or sometimes 10 years.

The familiar sight of stunted saplings standing alone or in small groups, huddled for protection on an upturned "clay root," or along

the edge of a swamp on cold, wet ground, or in very dry places where scarcely anything else can grow, gives evidence of the ceaseless pursuit of fires. The effect of protection upon the rate of growth, discussed under "Growth Under Fire Protection" (Pl. XVII), is very marked in contrast with the slow growth and accompanying stunted development more commonly seen.

The fire problem is great, but undoubtedly it can be solved by the organized cooperation of the private owner, the State, and the Federal Government, acting jointly in placing the responsibility and sharing the cost (fig. 5). The settling of the lands and the development of higher types of community organization will exert a helpful

FIVE YEARS OF FOREST FIRES



FOREST FIRE PROTECTION PAYS

FIG. 5.—Forest fire losses in Georgia and in New York.

economic influence, while the increasing scarcity of old growth and the advancing prices of lumber and turpentine will tend to interest owners to bring their cut-over lands into productiveness. Small owners are already in a position to afford a good measure of protection to the old fields, which constitute the source of their local supplies of timber, and to the cut-over lands, which afford grazing and help in keeping live stock over the winter.

RAZORBACK HOGS.

The native, or "razorback," hog is one of the greatest enemies of young longleaf pine. As an agent of destruction he probably holds next place to that of fire. In localities near settlements, where fires are infrequent, the hog easily becomes the chief factor in preventing the reforestation of longleaf. (Pl. XVIII.)

The piney-woods hog consumes large amounts of the seed, or mast; but probably his chief offense springs from his fondness for the thick, succulent bark on the taproot and lateral roots of young longleaf pines. In southeastern Texas the writer counted as many as fifty-two 2-year-old seedlings killed by hogs in 1 square rod, or at the rate of 8,320 per acre. It is likely that in the course of one day a hog often destroys as many as 200 to 400 young pines. Those from 2 to 5 years old probably suffer most, but not uncommonly saplings up to 10 years of age are killed. The spring season is the favored time for attack when the swamps are overflowed and food must be sought on the drier lands. In stripping the bark from the roots, sometimes the tops are left intact or are bitten off at the surface of the ground, and at other times the plants are pulled out of the

The question of future longleaf pine forests turns largely on controlling fires and "razorbacks." Millions of acres of young growth have been and are being destroyed by these agencies. Is the native hog worth while?

Two experimental tracts at Urania, La., after five years of protection against hogs, contained an average of 6,440 longleaf saplings per acre, as compared with an average of 8 per acre on two similar unprotected tracts.

ground. (Fig. 6 and Pl. XIX.) With the drying and hardening of the soil, or the exhaustion of the supply of trees, operations cease for the season. As a rule, a good stand of young longleaf will disappear completely in two to four seasons.

Although the "razorback" is widely and generally distributed, especially where stock laws are not enforced, the number of hogs present and the amount of damage accomplished appear to be variable, and in spite of the hog considerable young longleaf seems to get through the hog-danger period, only to go down in the losing battle with fires. No damage, so far as known, has been reported from blooded hogs, and with the passage of State-wide stock laws and the bringing of large tracts of land under farm management, the necessity for finding means for preventing damage from native hogs is lessening. In getting young longleaf stands started a good degree of protection against this class of hogs, if they are present, is very essential for at least the first five years.

INSECTS, DISEASES, AND WIND.

Various insects are known to attack longleaf pine. Damage by insects to fertile seeds, before being shed from the cone, has been reported. The southern pine beetle is well known because of the outbreaks that have occurred and in which large areas of pine timber have been killed. It seems that the remedy for preventing such losses in small operations consists chiefly in not cutting timber in the hot season; or, if some must be cut, in removing it without delay and either piling the brush and burning it in an opening or scattering it to dry out as quickly as possible. The trees infested with the beetle should be utilized at once. For information on this subject a copy of Farmers' Bulletin 1188, *The Southern Pine Beetle*, should be requested from the Division of Publications, U. S. Department of Agriculture; or a letter may be addressed to the Bureau of Entomology regarding this or other insect problems.

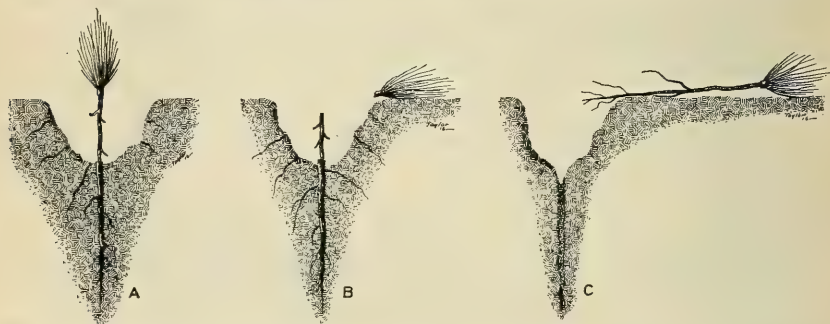


FIG. 6.—A, taproots stripped from 6 to 10 inches; B, top frequently broken off; C, seedlings pulled up with taproots usually 8 to 15 inches long, all roots stripped.

A cone-rust disease is known to be the cause of much injury in parts of Florida and some distance northward. It attacks the first-year cones and kills them after causing them to grow to an abnormal size. In parts of the palmetto region it is probable that this disease largely accounts for the scarcity of reproduction. A leaf blight is not infrequently seen defoliating small groups of seedlings before they get above the tall grass. The growth is checked but not otherwise affected.

Wind damage to longleaf pine is heavy, chiefly on turpentine timber (Pl. X); and occasionally tropical hurricanes make almost clean sweeps of timber. One of the largest sawmills in the South operated for about a year (1915-16) on such wind-thrown timber. The usual loss of old-growth timber from insects and wind is indicated by the results of the measurement of three "forties" in 1917 and of their remeasurement in 1920.¹⁰ The timber consisted of about 30 trees per acre, averaging 560 board feet each, or 16,780 feet per

¹⁰ The timber was located in the north-central part of Louisiana, and the measurements were made by members of the Yale Forest School.

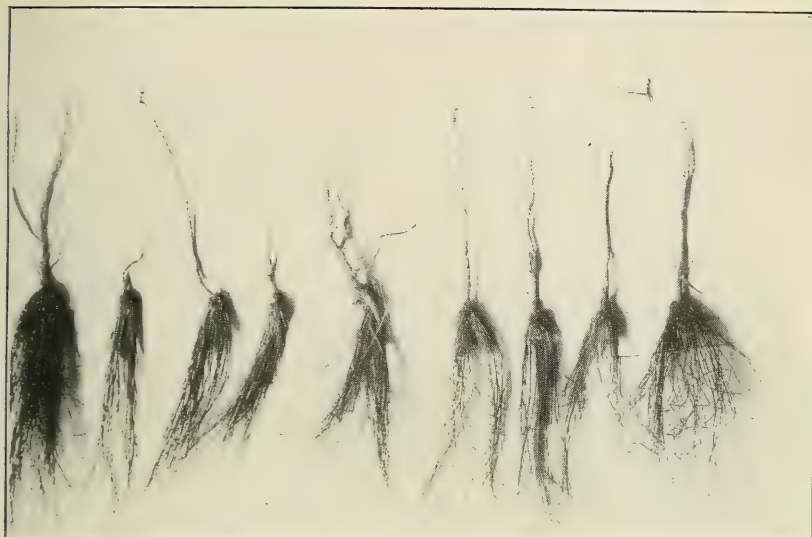


FIG. 1.—The native piney woods hog is one of the worst enemies of longleaf pine. These 2-year-old seedlings were dug out of the ground. In the spring, when the ground is soft and available food scarce, hogs eat the thick, spongy, succulent bark around the taproot and larger laterals, thereby killing millions of seedlings annually. The saplings, about 2½ years old, during the course of the meal were pulled completely out of the ground and left in their present condition. Others had lost their tops and on some the roots were skinned and girdled without much damage to the tops.



FIG. 2.—On 1 square rod in eastern Texas, selected at random, there were found 38 longleaf seedlings recently killed by hogs, and 5 living. This is a slaughter of 6,080 per acre. The tract in east Texas was cut for logs in 1896 (20 years prior) and again cut for piling 10 years later, but hardly a young tree has escaped the hogs and fires.

DESTRUCTION BY NATIVE RAZORBACK HOGS.



FIG. 1.—Cattle grazing on a farm in lower South Carolina, established on flat, cut-over longleaf "crawfish" lands. The growing of longleaf pine is to be favored, because it usually grows open enough so as not to interfere with success in live stock. The plowed furrows mark the margin of a strip that is burned yearly as a fire guard to protect young longleaf stands. (Berkeley County, S. C.)

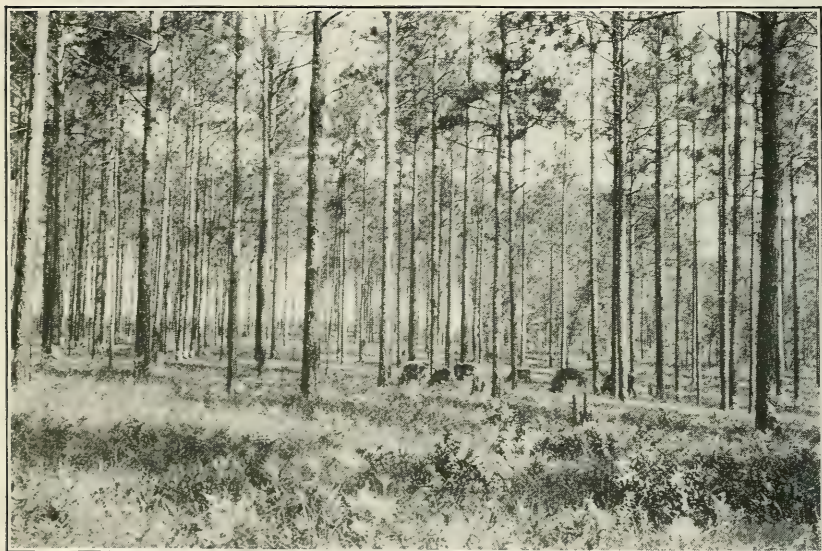


FIG. 2.—Longleaf pine stands about 40 years of age on an old field in northeastern Florida. There are about 90 trees per acre, of which about 50 are cupped for the virgin crop. The dominant trees are mostly 60 to 70 feet in height and 10 to 15 inches in diameter and would saw out about 6,000 board feet, or about one-half the yield of a well-stocked stand at this age. The land, however, has furnished continuous grazing, timber from time to time, and now about 60 cups per acre. It is being carefully worked so as not to injure the trees. (Baker County, Fla.)



FIG. 1.—Because of fires, only a very small percentage of the young trees ever reach beyond the small sapling stage. The location shown is in Louisiana, only 5 miles from a large paper-pulp mill which uses over 500 cords of wood daily, and will greatly need supplies of pulpwood within a few years.



FIG. 2.—Such timber as this, requiring from 100 to 150 years, if produced in the future will be mostly grown under State or National control rather than in private ownership. The State and Federal Governments, cooperating with the private owner, have a large and important place in any program of reforestation.



**SECOND-GROWTH LONGLEAF PINE, ABOUT 40 YEARS OLD.
GROWING IN A WELL-STOCKED STAND.**

The trees are tall and the volume of timber per acre is large. This stand might profitably be thinned by turpentine and then cutting the trees to be removed. If no waste is permitted, such stands yield large money returns.

acre. During the 3-year period, the loss was 41 trees, mostly from 24 to 30 inches in diameter, scaling an average of 654 feet each, or an average loss of 222 board feet per acre. Most of the trees were killed by insects or blown down. Fires, which had run every year, caused the death of about 4 trees of smaller sizes. No evidence appeared of unusual wind or insect damage having been wrought.

TIMBER AND LIVE STOCK.

A large lumber company, operating exclusively in southern Mississippi and eastern Louisiana, after a general survey has estimated that about one-quarter of its cut-over lands lying mostly on the

On the poorer lands no other crop promises to pay so well as timber growing.

The chief sources of future economic production on the vast area of cut-over lands of the South will unquestionably be agriculture, grazing, and timber growing. The advantages for investments in the growing of pine timber in the southern region are: (1) An abundance of land of relatively low value in excess of all that can possibly be used during the next few decades for all other purposes; (2) a very long growing season, resulting in rapid timber production; (3) easy logging and shipping conditions; and (4) relative proximity to the large northern and eastern markets.

upper coastal plain soils is adapted to farming, and that the bulk of the land is better suited to other uses. The great flatwoods section, which was originally forested, chiefly with longleaf pine, offers little promise of being wanted extensively for cultivated crops. Only 10 to 15 per cent of this natural soil division and of the near-by lands is now in farms. The utilization in the near future of these nonproductive lands for timber growing and for grazing purposes is unquestionably the only logical solution of the problem (Pl. XX).¹¹

The cut-over lands of the South that are practically idle because they contain little or no forest reproduction or young growth are estimated at not less than 30,000,000 acres. Of this amount by far the greater portion consists of longleaf pine lands, an area equiva-

¹¹ Agriculture Bulletin 827, "The Cut-over Pine Lands of the South for Beef Cattle Production."

lent to more than all the forest lands of France. The amount of permanent "forest soil" in the South, or land which will eventually be found to be better adapted to forest purposes than to any other use, is not known, but the area is extensive. Plate XXI shows the kind of timber which, if it is grown at all in the future, will probably be produced under some form of public land control or ownership. Either acting alone or in cooperation with the Federal Government, the State after acquiring tracts of the poorer classes of southern pine cut-over lands, would doubtless be in the best position to begin building up forests for a sustained yield of turpentine and limber. Such action, if taken, would probably be more as an example to show how the thing may be done. It is believed that at the present rate of development private enterprise in the South will soon take a serious interest in managing forests of longleaf and slash pines for continuous production (Pl. XXII). Grad-

There are millions of acres of lands in the Southern States which will become valuable to the owner and the State only by the growing of pine timber. The protection and reforestation of these lands mean permanent industries, permanent homes, good roads, and good schools.

ually the small owner will adopt the system, making such changes as may seem desirable to meet the conditions of private ownership.

While it is growing a crop of longleaf or of slash pine for turpentine and timber, much of the land at the same time can be grazed without detriment to the growth of the timber. This means of securing a double source of income is open alike to the small farmer and to the large land company. If the farmer's principal business happens to be the growing of crops, cattle and trees make a good combination for additional profit.

The best utilization of southern cut-over pine lands and the method of bringing it about constitute a problem affecting the interests of owners of farms, large landholders, the State, and the Nation. The present state of waste and idleness of these lands places a financial burden upon the owners, and, through the decrease in taxable values, upon the State and Nation.

It appears practically certain that, however large the demand may be for farming and grazing lands, vast areas of the poorer classes of land will remain idle during the next half century or more unless they are devoted to timber growing.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1062



Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief, in cooperation with Purdue University
Agricultural Experiment Station.

Washington, D. C.

PROFESSIONAL PAPER

April 22, 1922

RELATION OF THE CHARACTER OF THE ENDOSPERM TO THE SUSCEPTIBILITY OF DENT CORN TO ROOT ROTTING.

By JOHN F. TROST, *Assistant Pathologist, Office of Cereal Investigations, Bureau of Plant Industry, and the Department of Botany, Purdue University Agricultural Experiment Station.*

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EAR CLASSIFICATION BASED ON STARCHINESS.

Early in the course of investigations of the root, stalk, and ear rots of corn, differences were observed in the amount of starch in the various ears from which kernels were being germinated to determine the extent and character of seed-ear infections. These differences were noticeable not only among different varieties, but often equally so among the individual strains within a single variety.

It seemed important to determine what physical characters of the ear or kernel, if any, might be used in recognizing and eliminating infected seed ears. Obviously, such a procedure would be valuable in reducing the necessity for a detailed germination test of each ear.

The ears were classified on the basis of the endosperm. The starchy endosperm appears opaque when the kernel is held up to the light, but the portion containing horny endosperm is more or less translucent. Six degrees or types of starchiness were recognized and

designated as types A to F, inclusive (Pl. I). Where the starch zones of the crowns and tips of the kernel were completely united and the kernel was entirely opaque to transmitted light, it was designated as type A, or starchy. Kernels of which three-fourths of the endosperm was starchy were designated as type B. Kernels in which half of the endosperm was starchy were classed as type C, and those in which about one-fourth of the endosperm was starchy represent type D. Kernels showing only a narrow band of starch at the crown were designated as horny, or type E, and a few strains in which practically all of the endosperm was horny were designated as very horny, or type F. These types are shown in Plate I.

With this classification it was easy to separate the character of starchiness from that of indentation, with which it has been too frequently confused. Starchiness is characteristic of chaffy, immature ears, but is not necessarily associated with normally matured ears of rough indentation. Ear types commonly encountered are illustrated in Plate II.

Most of the ears studied fell within the range of types C, D, and E. Some strains averaged "C" in composition, and some northern Indiana strains of Ninety-Day corn averaged "F" in composition, or very horny. The larger, later maturing strains grown in the southern part of the State seemed to show some tendency to be more starchy than those grown in the northern part.

RELATION OF ENDOSPERM CHARACTER AND EAR INFECTION.

The results of a study of the relation of ear composition to ear infection are shown in Table 1. This study was made upon representative ears supplied to this office for germination and field experiments during 1918 and 1919 by a number of the more prominent seed-corn growers of Indiana. On the basis of character of endosperm, the ears in each sample were separated into the two classes, starchy and horny, the dividing line being placed arbitrarily between types D and E. In studying the germination record of these ears, all ears were considered infected the kernels of which were characterized by growths of *Fusarium* spp., *Diplodia zeae*, or *Penicillium* spp. when accompanied by disorganized tissue surrounding the scutellum in each of duplicate germination tests made upon the limestone-base table germinator, as described by Hoffer and Holbert.¹

¹ Hoffer, George N., and Holbert, J. R. Selection of disease-free seed corn. Ind. Agr. Exp. Sta. Bul. 224, 16 p., 20 fig., 1918.

TABLE 1.—*Infection by rot-producing organisms in starchy and in horny ears of several varieties of dent corn obtained from different parts of Indiana during 1918 and 1919.*

Source of sample (Indiana).	Variety.	Average character.	Number of ears studied.			Infected ears (per cent).	
			Total.	Starchy.	Horny.	Starchy.	Horny.
Woodburn.....	Champion.....	F	100	42	58	6.17	4.45
Valparaiso.....	Ninety-Day.....	F	100	24	76	58.33	43.24
Fort Wayne.....	Early Yellow Dent.....	D	100	40	60	57.89	17.59
Rensselaer.....	Silvermine.....	E	100	44	56	50.00	33.33
La Fontaine.....	Reid Yellow Dent.....	E	150	42	108	50.00	28.57
Noblesville.....	do.....	E	100	22	78	20.00	16.50
Forest.....	do.....	E	100	15	85	42.86	35.00
Battle Ground.....	do.....	E	100	24	76	50.00	23.08
Sullivan.....	do.....	E	100	37	63	43.75	37.04
Pennville.....	do.....	D	100	59	41	46.20	38.90
Delphi.....	do.....	D	100	34	66	76.92	41.67
Fort Branch.....	do.....	D	150	52	98	68.40	47.20
New Richmond.....	do.....	C	200	168	32	70.33	35.29
Shelbyville.....	Johnson County White.....	E	100	53	47	66.67	58.33
Do.....	do.....	D	400	304	96	55.27	41.67
Hope.....	do.....	D	100	54	46	51.56	34.78
Total.....	.....	.....	2,100	1,014	1,086	.....	.....
Average.....	.....	.....	.....	63	68	50.90	33.54

In every case the ears of the starchy class were characterized by a larger percentage of infections. This was especially noticeable in those strains which averaged a half (C) or a quarter (D) starchy. A very horny sample from Woodburn, Ind., carried a very low amount of ear infection. In this sample the differences between the horny and starchy groups were practically negligible. The most extreme difference occurred in a lot of starchy ears of Reid Yellow Dent from New Richmond, Ind. In this lot 70.33 per cent of the starchy ears were infected, compared with only 35.04 per cent of the horny ears. In general, such extreme variations have not been encountered. When all the samples subjected to this germination test, totaling 2,100 ears, are considered together, practically equal numbers of horny and of starchy ears are represented. The average proportion of infection in the horny group was 33.5 per cent and that in the starchy group 50.9 per cent, representing 17.4 per cent fewer infected ears in the horny group.

These data indicate that progress may be made in securing better seed ears by selecting those ears within the strain which have the more horny composition.

Though these data concerning ear infections of different varieties are meager, it is evident from the variations encountered among the nine separate strains of Reid Yellow Dent under comparison that as great variations in the character of the endosperm may occur among strains as among distinct varieties. The field performance of these strains indicates further that just as large variations in starchiness may occur among strains within a variety which require the same length of growing season.

With increased starchiness a number of factors operate toward increasing the number of ear infections. Immature seed ears are characterized by starchiness. Some of the starchy ears may come from the normally late-maturing strains, in which case the ear is exposed to weather conditions more favorable for infection by the root-rotting organisms during the period of ripening. Because of their high moisture content, such immature ears afford a good medium, even after harvest, for the development of these organisms when introduced from external sources. It has already been observed, however, that larger percentages of ear infection occur in the starchy groups of seed ears from strains with practically the same length of growing season. Field observations indicate that such seed ears are obtained from stalks suffering from an unbalanced food supply. Perhaps the main contributing factor is a root-rotted condition of the parent stalk itself. These factors merely furnish additional argument in favor of the practice of selecting seed ears from the stalk in the field.

RELATION OF KERNEL STARCHINESS TO PATHOLOGICAL PERFORMANCE.

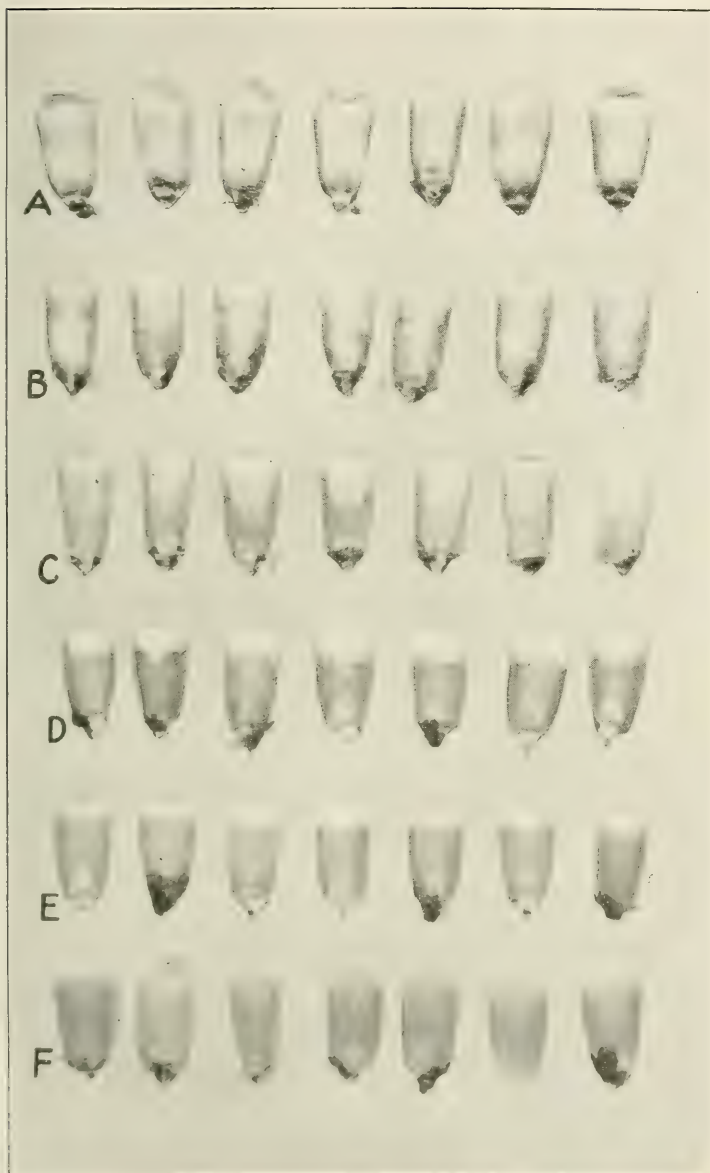
As starchy seed ears are more frequently infected with root-rot organisms than the more horny ears, it has seemed important to determine the relation of kernel starchiness to pathological performance in the field. Decreased stands and yields follow the planting of kernels from infected seed ears, as has been determined by the writer and by Duddleson and Hoffer² (unpublished data) and previously reported in the course of these investigations by Hoffer and Holbert.³

Because of the larger proportion of infections in the starchy seed ears, the planting of seed from these two groups without regard to the germination records would be expected to show superior yields from the more horny seed. In the study of the field effects of ear infection during the seasons of 1918, 1919, and 1920, approximately equal numbers of infected and of disease-free ears from the horny and the starchy groups were used in ear-to-row experiments. All rows were 75 hills in length. Only ears giving 100 per cent germination in the laboratory were used for seed.

The data from these plats have been summarized in Table 2 on the basis of starchiness of kernels. In this table the field performance of the horny groups of ears in each experiment has been taken as 100 per cent. The figures represent the percentage of decrease incurred through the use of the starchy seed ears. In all but one

² Duddleson, B. H., and Hoffer, G. N. The improved rag-doll germinator for the elimination of diseased seed corn. (Manuscript.)

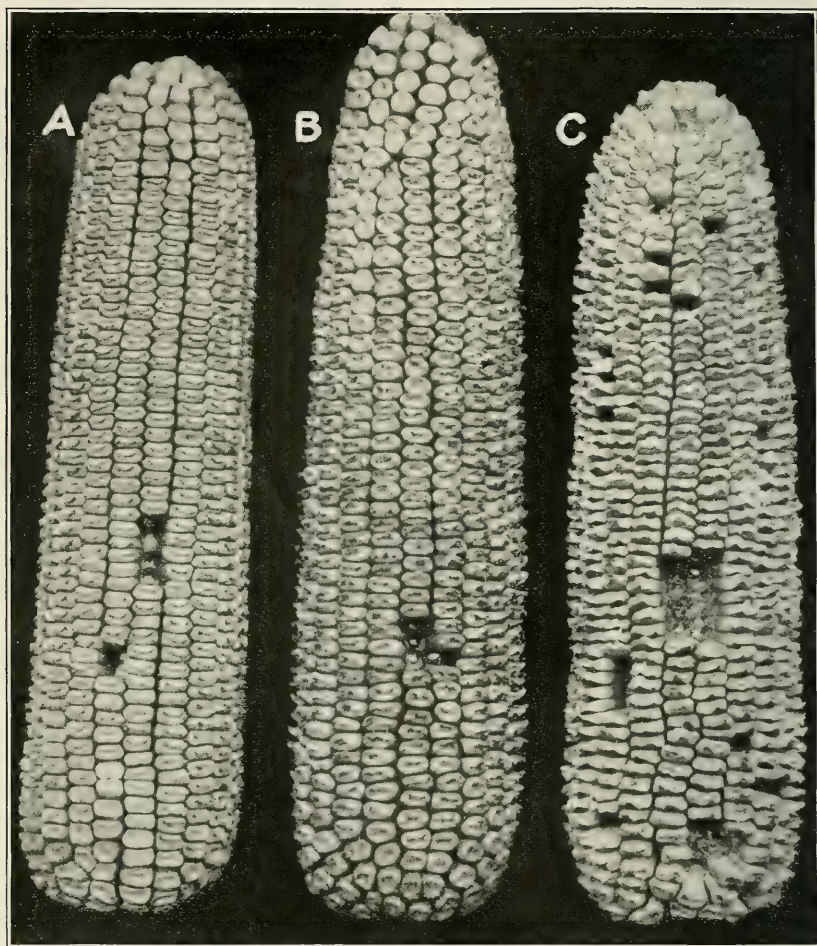
³ Op cit.



KERNEL TYPES OF CORN SHOWING GRADATIONS OF STARCHINESS.

A, Starchy; *B*, three-fourths starchy; *C*, half starchy; *D*, one-fourth starchy; *E*, horny;

F, very horny type.



COMMON TYPES OF SEED EARS OF REID YELLOW DENT CORN, ILLUSTRATING THE RELATION OF INDENTATION AND STARCHINESS.

A, Normally matured, smoothly indented, horny ear; *B*, normally matured, roughy indented, horny ear; *C*, chaffy, immature, roughy indented, extremely starchy ear.

experiment, that at Woodburn, Ind., the horny ears produced the higher initial stand in the field. This difference in stand was maintained throughout the growing season, as shown by the figures for initial stand compared with those for final stand, taken just previous to harvesting. This inferiority in stand was reflected in the decreased yield of the starchy group. Results due to differences in stand were eliminated by correcting the yields of both groups to perfect stand for each experiment. In this manner the actual superiority of the horny seed ears becomes apparent. Thus, while the average difference in final stand in the 11 experiments was 2.78 per cent less for the starchy ears, this was accompanied by an average reduction in actual yield of 5.57 per cent. Upon correcting both groups to perfect stand, the average decrease in yield incurred through the use of starchy seed ears amounted to 4.2 per cent.

TABLE 2.—*Actual and corrected yields from starchy and from horny ears of dent corn in ear-to-row tests in Indiana in 1918, 1919, and 1920.*

Location of plat (Indiana).	Number of ears used in each plat.			Decrease resulting from the use of starchy seed (per cent).			
	Total.	Starchy.	Horny.	Stand.		Yield.	
				Initial.	Final.	Actual.	Corrected to perfect stand.
Fort Wayne.....	45	19	26	4.12.	4.26	6.51	5.17
Woodburn.....	48	20	28	(1)	3.04	1.26	4.44
Valparaiso.....	46	11	35	4.30	5.48	8.21	4.83
Noblesville.....	50	11	39	(1)	1.47	.93	.89
Pennville.....	44	26	18	(1)	.78	7.24	6.96
Delphi.....	50	17	33	(1)	1.73	9.21	3.57
Fort Branch.....	37	21	16	9.86	6.21	8.38	4.69
New Richmond.....	80	62	18	(1)	.54	6.40	6.21
Shelbyville.....	45	35	10	4.64	5.05	6.50	4.05
Cannelton.....	20	5	15	1.60	1.34	2.39	1.88
Rockport.....	49	21	27	(1)	.72	4.20	3.47
Average decrease from the use of starchy ears.....					2.78	5.57	4.20

¹ Initial stand records were not made in these experiments.

SUSCEPTIBILITY OF DISEASE-FREE SEED EARS.

To determine the relative susceptibility to root rotting of the horny and starchy groups of seed, a field experiment was outlined in 1920 in which alternate rows were planted with kernels from selected horny and starchy disease-free ears of a single strain of Reid Yellow Dent. In the horny group most of the ears were classified as type F. In the starchy group no ears less than half starchy (type C) were employed. This experiment was conducted at Bedford, Ind., and was duplicated in a fertilizer plat at Linden, Ind. The plats were each 1 acre in size. Owing to evident errors introduced by marked soil inequalities, the taking of notes was dis-

continued on the Linden plat after recording the initial stand. The data at Bedford were taken throughout the growing season and include the harvest results.

A complete analysis of the field results obtained in this experiment is given in Table 3. At Bedford the average reduction in initial stand due to planting starchy ears was 4.26 per cent. The reduction at Linden amounted to 10.21 per cent. The weather conditions following the planting of this plat were very unfavorable for germination. Thus, it appears that starchy ears are especially unsatisfactory for seed in districts where weather conditions are likely to make it difficult to secure a good stand. As in the earlier experiments, the difference in stand was maintained throughout the growing season. As the difference between the initial and the final stands is made up of losses sustained through blighting, and principally through seedling blight, the results indicate that the susceptibility of the two groups to such blighting is equal.

TABLE 3.—Yields from starchy and from horny disease-free seed of a strain of Reid Yellow Dent corn, planted in alternate rows at Bedford, Ind., in 1920.

Group.	Number of ears used.	Agronomic data (per cent).										Yield per acre (bushels).	
		Stand.		Plant vigor.			Stalk condition.			Quality of ears.			
		Initial.	Final.	Vigorous.	Semivigorous.	Weak.	Barren.	Leaning.	Down.	Good.	Nubbins.	Actual.	Corrected to perfect stand.
Horny.....	19	86.9	83.7	61.8	17.9	3.7	7.2	44.5	1.7	46.7	29.5	38.43	40.7
Starchy.....	17	83.2	79.6	51.6	20.1	7.3	11.4	45.9	2.6	41.0	27.4	32.09	35.0
Difference:													
Actual.....		3.7	4.1	10.2	— 2.2	3.6	4.2	1.4	.9	5.7	—2.1	6.34	5.7
In favor of horny ears.....		4.26	4.84	16.5	—12.6	97.3	58.3	3.14	53.0	12.2	—7.2	16.41	14.0

Records were taken on the relative vigor of early growth 40 days after the date of planting. At this time the plants averaged 24 inches in height. They were classified arbitrarily as vigorous, semivigorous, or weak, and records for the entire plat were taken on the same day by one person, thus insuring the maintenance of the same standard of classification. Rows from the horny seed contained larger numbers of strong plants and markedly smaller numbers of weak plants than those from starchy ears. These results are in agreement with the studies reported by Hughes,⁴ in which he found that horny kernels gave a more rapid early growth than starchy ones. His data covered a period of only 20 days, however, at the end of which

⁴ Hughes, H. D. The germination test of seed corn. Iowa Agr. Exp. Sta. Bul. 135, pp. 305-379, 22 fig., 1913.

time the seedlings from the starchy kernels had practically caught up with the others. His opinion that the advantage ordinarily obtained by rapid early growth is not retained throughout the season is not borne out by these Indiana experiments. In the Bedford experiment the advantage of stronger early growth is reflected at harvest time in the higher proportion of good ears and the lower percentage of barren stalks.

Leaning and down stalks have been considered valuable external indications of a root-rotted condition. Just prior to harvesting, a heavy windstorm lodged about 50 per cent of the stalks. Counts of the leaning and down stalks made immediately following the storm showed stalks from the horny group to be slightly more storm resistant.

The rows from horny seed ears also were superior in yield to those from the starchy ones. After making corrections to eliminate errors introduced by differences in stand, the starchy ears still produced 14 per cent less corn than the horny ears. These data furnish direct evidence of the correlation of resistance to root rots in corn plants of dent varieties with a horny character of endosperm and of the susceptibility of those with a starchy endosperm.

SUMMARY.

Ears of seed corn of dent varieties characterized by starchiness of endosperm have been found to be infected with root-rot organisms more frequently than seed ears characterized by horny endosperm in the same seed lots.

Starchy ears of corn of dent varieties produce larger numbers of weaker growing plants, more susceptible to root rots in the field, than do ears more horny in composition.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1063

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.



May 29, 1922

SWEET-POTATO STORAGE STUDIES.¹

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IMPORTANCE OF THE SWEET-POTATO CROP.

The sweet potato is second in importance of the vegetable crops, being exceeded in value only by the Irish potato. In 1920 approximately 1,085,000 acres of land in the United States were devoted to the production of sweet potatoes. The estimated production was 112,368,000 bushels, with a farm value of \$126,629,000. The greater portion of the crop is produced in a few of the Southern States, the important producing States being Alabama, Georgia, Mississippi, North Carolina, Texas, South Carolina, and Louisiana.

¹ During the progress of this work assistance was rendered by H. M. Conolly, formerly assistant horticulturist; F. E. Miller, formerly horticulturist; and C. J. Hunn, assistant horticulturist, Office of Horticultural and Pomological Investigations.

PRELIMINARY STUDIES.

In preparing for this investigational work on sweet-potato storage a study was made of the industry in the South. It was found that storage and marketing were by far the most serious problems confronting the grower at that time, but it was evident that little could be done on the marketing problem until the storage problem was solved. At the time these studies were made, careful estimates indicated that on the average the loss by decay was fully 30 per cent of the sweet potatoes stored in pits or banks, the common method of caring for the crop in the South, while in many cases the loss was complete. In addition to the loss due to storage rots, it was found that these potatoes were poor in quality when removed from the pits and decayed rapidly after they were placed on the market. From these preliminary studies it was evident that experimental work on sweet-potato storage was needed, especially in the South, where the bulk of the crop is grown, and that some method of storage was desirable which would give better results than the pit and bank methods.

Various types of storage houses had been used in some of the sweet-potato growing sections, but at this time there were very few storage houses in the South, and practically none of these were in the sections of States producing large crops of sweet potatoes. Various commercial sweet-potato regions, including New Jersey, Delaware, Maryland, Illinois, Iowa, and a few in the South, were visited, and studies were made of the types of storage houses and the materials and methods used in their construction, ventilation, heating, and management. The methods employed in harvesting and caring for the sweet-potato crop were also noted, and a study was made of the results obtained in the various types of houses under the different methods employed in handling the sweet-potato crop. From these observations it was thought that the first step should be to devise a type of house that would meet the needs of the South. The good features of all the storage houses that had been visited were combined and a plan was made by the senior writer in 1912. This plan, somewhat modified, was later published in *Farmers' Bulletins* 548 and 970.

In 1912 a few houses were built in Alabama and Mississippi, according to these plans, and observations were made on the keeping of sweet potatoes in them. This work was done during the first year in cooperation with the agricultural colleges in Alabama and Mississippi, but after that active cooperation ceased. The work was continued in these and other States by the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry. The houses built in 1912 were so successful that they served as demon-

strations and object lessons, with the result that thousands of similar houses are now in use.

OBJECTS OF THE EXPERIMENTS.

Many problems arose relative to the management of storage houses built according to the plans as originally made and as modified from time to time. It became apparent that more information was needed on the problems involved. These were—

- (1) The factors which hasten the decay of sweet potatoes in storage.
- (2) The best methods of reducing the losses due to decay and to excessive shrinkage.
- (3) The effects on shrinkage and decay of different methods of handling sweet potatoes.
- (4) A comparison of varieties of sweet potatoes with reference to loss in storage from shrinkage and decay.
- (5) The effects on the keeping quality of sweet potatoes of temperature and humidity in the storage house.

METHODS OF PROCEDURE.

Experimental work on sweet-potato storage was begun in 1912 and has been continued every year since. During the first four years all the experiments were conducted in houses owned and controlled by farmers or commercial firms, and the management was not entirely under the control of the investigators. During the five years 1916-17 to 1920-21, inclusive, the work was carried on in a storage house erected for this purpose on the Arlington Experimental Farm at Rosslyn, Va. This house has been under the complete control of the investigators.

In all of the experiments it was the aim of the investigators to have all the conditions identical, with the exception of the particular one being studied. Where the conditions were not alike the results are not considered in this bulletin.

In all the experiments conducted in storage houses the sweet potatoes were subjected to a curing process for a period of two or three weeks, the length of time depending upon the weather and the condition of the potatoes. The curing consists of reducing the moisture content of the potatoes by means of artificial heat with thorough ventilation. The temperature during the curing period was usually maintained between 80° and 90° F. by means of heating apparatus until the potatoes were cured, as evidenced by the "feel" when handled or by the appearance of sprouts. When the potatoes were cured the temperature was gradually lowered to the desired point. The average temperature maintained in the different rooms in the experimental house is shown in figure 1.

Ventilation was provided by means of openings in the floor and through the ceiling and roof, as illustrated in figure 2, and by means

of doors and windows. During the curing period all ventilators were kept open. During the day the windows and doors also remained wholly or partially open unless the weather was cold or the atmosphere was very moist. By means of heat and ventilation, moisture was prevented from depositing on the interior of the stor-

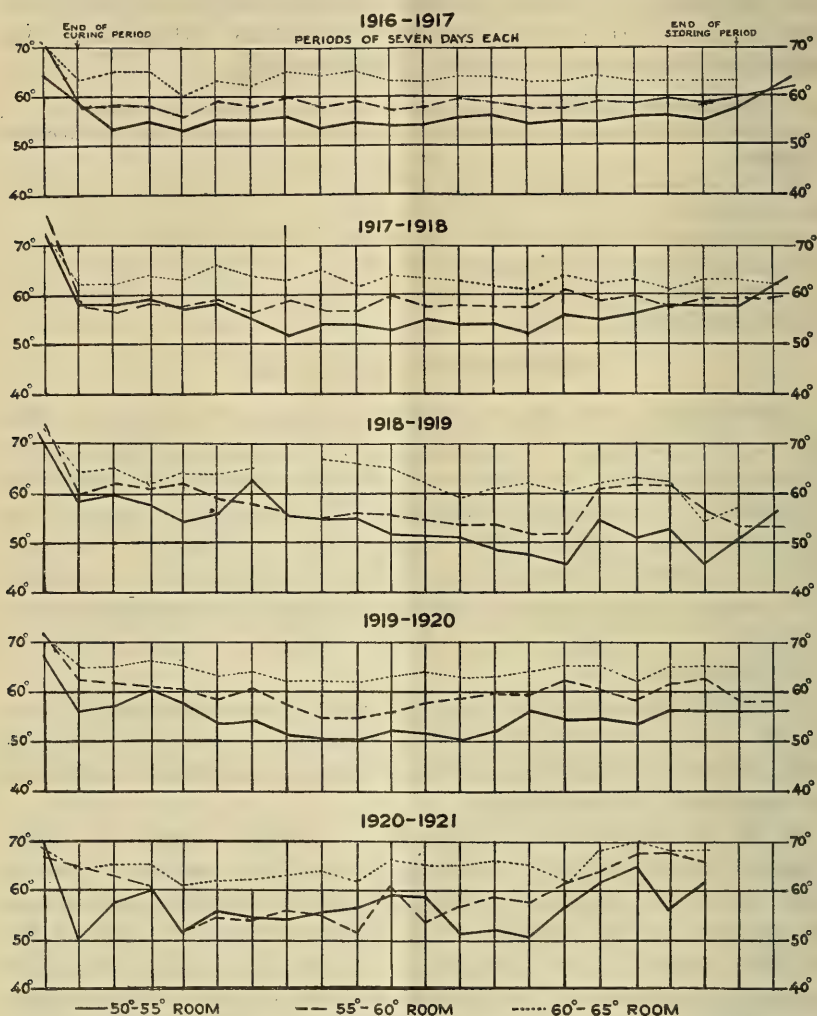


FIG. 1.—Diagrams showing the average temperature in the storage house at the Arlington Experimental Farm, Va.

age house. During rainy or cold weather the doors and windows of the house were kept closed.

Temperature and moisture variations in the experimental storage house were recorded by means of thermographs and hygrothermographs. These instruments were standardized by comparison be-

fore beginning work each year and checked at occasional intervals while in use; they were all of the 7-day type, and the record sheets were changed each Monday, thus giving a continuous record for each storage season.

The selection and the grading of the potatoes for each test were done by the investigators or by careful men under their direction. Shrinkage and decay were determined by weight. The percentages of shrinkage as recorded in the tables are progressive; that is, the record of loss at any period shows the total loss from harvest until that time.

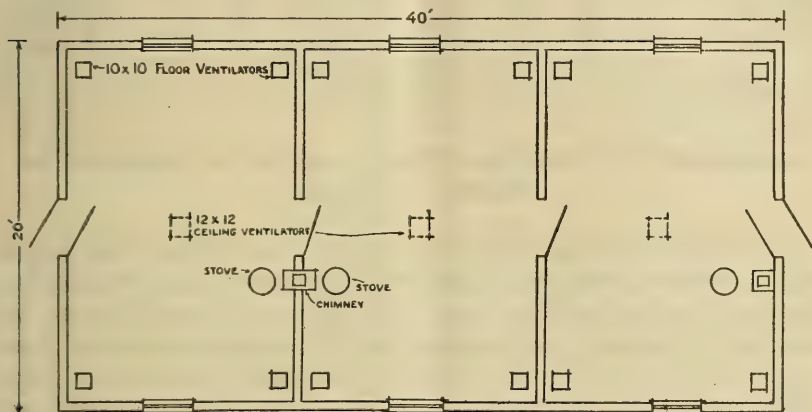


FIG. 2.—Plan of the experimental storage house at the Arlington Experimental Farm, Va.

COMPARISON OF THE KEEPING QUALITIES OF SWEET POTATOES UNDER CAREFUL AND UNDER COMMERCIAL HANDLING.

To determine the effects of methods of handling on the keeping qualities of sweet potatoes, five tests were made to compare careful handling in the field and in the storage house with ordinary commercial handling. These tests were all made in good houses in the South. The "careful handling" was done by men engaged in the experimental work, and all the conditions except the one under investigation were kept the same. Table 1 gives the results of the five tests in the four years 1912-13 to 1915-16, inclusive.

Attention is called to the fact that both crate storage and bin storage were used in the tests. Under careful handling the minimum shrinkage was 5 per cent and the maximum 9.39, the average being 7.52 per cent. The minimum shrinkage under commercial handling was 7.40 per cent and the maximum 20.40, with an average of 10 per cent. The average amount of decay was 0.45 per cent under careful handling and 3 per cent under commercial handling.

TABLE 1.—*Comparison of the keeping quality of sweet potatoes under careful and under commercial handling.*

[Shrinkage and decay averages for two varieties in five storage-house tests in Southern States during four seasons.]

Variety.	Test No.	Careful handling.				Commercial handling.				
		Weight at harvest time.	Time in storage.	Shrinkage.	Loss due to decay.	Weight at harvest time.	Time in storage.	Shrinkage.	Loss due to decay.	Storage receptacle.
		<i>Pounds.</i>	<i>Days.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Days.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Nancy Hall.....	1	3,062	161	5.00	0.50	3,062	161	7.40	1.00	Bins.
Dooley.....	2	120	125	9.10	.93	120	125	11.60	2.08	Crates.
Nancy Hall.....	3	45	125	9.39	5.56	45	125	20.40	15.56	Do.
Dooley.....	4	42	131	8.33	2.00	42	131	10.70	5.00	Do.
Nancy Hall.....	5	9,510	114	8.30	.41	110,663	114	10.10	3.04	Bins.
Total.....		12,799				113,932				
Average.....			131	7.52	.45		131	10.00	3.00	

COMPARISON OF HOUSE STORAGE AND BANK STORAGE OF SWEET POTATOES.

To compare the keeping quality of sweet potatoes in storage houses and in outdoor banks or pits, several experiments were conducted in the South during the three years 1913-14, 1914-15, and 1915-16. In each test the methods of handling and all conditions were the same, excepting the kind of storage used. The sweet potatoes were carefully handled for both types of storage and the banks were very well made; in fact, the banks were much better than the average. Sweet potatoes are not stored in banks in the North and to only a small extent in the colder portions of the South. In regions where freezing occurs sweet potatoes stored outdoors in any kind of banks are in danger of chilling, even though protected from freezing. Table 2 gives the results of storing 10 lots of sweet potatoes in houses and in banks.

Table 2 shows that the percentage of decay of sweet potatoes stored in houses ranged from 0.5 to 2 per cent. In banks the variation was from 4 to 40 per cent. The average decay of all the tests was 1.2 per cent in houses and 14.33 per cent in banks. The length of time the comparable lots of sweet potatoes were in storage was not always the same, but where there was a difference the shorter period was for those in the banks. As already suggested, the potatoes stored in these particular banks kept in much better condition than in the usual banks. This was due to the careful handling of the potatoes and to the making of good banks.

Many ordinary banks and pits of potatoes were examined during these studies. Generally the proportion of decay was between 25 and 50 per cent, and in some cases 100 per cent.

TABLE 2.—*Relation of the place of storage to the keeping quality of sweet potatoes.*

[Percentage of loss due to decay in a storage house and in outdoor banks and pits.]

Variety.	Test No.	Year.	In storage house.			In banks or pits.		
			Time in stor- age.	Weight at harvest time.	Loss due to decay.	Time in stor- age.	Weight at harvest time.	Loss due to decay.
			<i>Days.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Days.</i>	<i>Pounds.</i>	<i>Per cent.</i>
Triumph.....	1	1913-14	137	6,000	0.60	124	42,000	10.00
Nancy Hall.....	2	1914-15	106	84,000	.60	106	4,500	17.30
Nancy Hall.....	3	1915-16	118	48,000	1.50	102	18,000	33.30
Nancy Hall.....	4	1915-16	103	90,000	2.00	103	30,000	11.60
Triumph.....	5	1915-16	115	372,000	1.50	108	12,000	7.30
Nancy Hall.....	6	1915-16	110	168,000	.60	110	6,000	6.50
Nancy Hall.....	7	1915-16	123	120,000	.50	120	1,800	6.40
Mixed varieties.....	8	1915-16	114	48,000	1.00	114	60,000	4.00
Nancy Hall.....	9	1915-16	110	48,000	1.75	110	18,000	35.00
Nancy Hall.....	10					110	12,000	40.00
Total.....				984,000			204,300	
Average.....			115		1.20	111		14.33

It is impossible to control the temperature and moisture in banks, therefore in unfavorable seasons nearly all potatoes stored in them are lost by decay. This was the case in many sections of the South during the cold winter of 1917-18, when the banked potatoes froze. More labor is required to store potatoes in banks than in houses, as the pits must be made each year. It is not always possible to remove the potatoes from banks when wanted, because of unfavorable weather conditions, as it is not safe to open a bank of potatoes during cold or rainy weather. Potatoes which have been stored in banks are of low quality and decay rapidly, probably owing to lack of complete curing resulting in a watery potato. But even if potatoes stored in banks kept as well as those in storage houses, it would still be desirable to store in houses because of their greater convenience.

COMPARISON OF THE KEEPING QUALITIES OF INJURED AND UNINJURED SWEET POTATOES.

Some injury will result even with the most careful methods of harvesting and handling sweet potatoes. The plow or other harvesting implement cuts and bruises some of the potatoes. Some bruising is incidental to handling in the field and in storing. To determine the effects of cutting and bruising on shrinkage and decay in storage, potatoes injured at digging time were sorted and kept separate. For comparison, lots of uninjured potatoes of the same varieties were kept under like conditions. Three standard varieties were used in this experiment, which was conducted in the experimental storage house at the Arlington Experimental Farm. The results of this experiment are given in Table 3.

TABLE 3.—*Relation of cut or bruising injury to the keeping quality of sweet potatoes.*

[Shrinkage and decay averages for three varieties kept at a temperature of 50° to 55° F., seasons of 1917-18 and 1918-19.]

Variety and condition.	Average weight at harvest time.	Shrinkage during curing, 19 days.	Shrinkage at end of—					Weight at end of storage period.	Loss due to decay, 164 days.	
			51 days.	82 days.	111 days.	141 days.	164 days.			
Uninjured:	<i>Pounds.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
Big-Stem Jersey.	142.56	6.59	8.02	9.42	10.88	12.09	13.54	123.25	1.81	1.27
Nancy Hall.	140.00	7.14	8.46	9.69	11.03	12.12	13.10	121.56	.84	.60
Southern Queen.	153.09	7.83	9.12	10.49	12.00	13.21	14.69	130.59	.59	.38
Total.	435.66							375.41	3.25	
Average.		7.23	8.55	9.88	11.33	12.49	13.83			.75
Injured, cut, and bruised:										
Big-Stem Jersey.	73.25	14.44	19.75	23.59	27.09	30.33	33.83	48.47	20.16	27.52
Nancy Hall.	46.06	18.52	21.51	23.88	26.19	27.99	29.51	32.47	4.28	9.29
Southern Queen.	71.97	12.55	14.67	16.54	18.64	20.06	21.88	56.53	1.94	2.69
Total.	191.28							137.47	26.38	
Average.		14.83	18.26	21.01	23.69	25.91	28.13			13.79

Every potato in the damaged lots was either cut or bruised. Table 3 shows that for every period the shrinkage of the injured sweet potatoes was much greater than that of the uninjured ones. The exposure of the cut surfaces and the drying up of the decayed sweet potatoes caused a higher shrinkage in the injured lots. At the end of the storage period the average shrinkage of the three varieties was 28.13 per cent for the injured and 13.83 per cent for the uninjured potatoes. The Big-Stem Jersey variety showed the highest percentage of shrinkage and also the largest proportion of decay in the injured lots. The Southern Queen had the smallest percentage of shrinkage of the injured lots. The extent of decay was considerably greater in the injured than in the uninjured lots. The average loss for the three varieties was 0.75 per cent in the uninjured lots and 13.79 per cent in the injured lots. The greatest loss was in the Big-Stem Jersey, being 27.52 per cent in the injured lot in comparison with 1.27 per cent for those not injured. The proportion of decay in the injured lot of the Southern Queen variety was very small, being only 2.69 per cent, or less than one-third as much as in the Nancy Hall and less than one-ninth as much as in the Big-Stem Jersey. It is a matter of common observation that the Southern Queen will stand rough handling better than any of the other standard varieties. The cut surfaces of this variety heal rapidly under good storage conditions. It should not be inferred, however, that great care in handling it is not important, for under less favorable conditions the loss might be much higher. The excessive shrinkage and the poor appearance of the injured potatoes reduce their market value materially and are of sufficient importance to justify

careful handling. The conditions under which this experiment was conducted were more favorable than would ordinarily exist in commercial practice. The loss due to decay was not as great as would usually occur. Under ordinary conditions the cut and bruised sweet potatoes should be disposed of at harvest time.

COMPARISON OF THE PRACTICES OF SORTING AND NOT SORTING STORED SWEET POTATOES.

It has been very generally believed that when sweet potatoes begin to decay in storage they should be sorted to pick out the diseased ones. Observations on this point indicated that this sorting was of doubtful value. Experiments were begun in 1912 and continued in each of four years to determine whether it is safe to pick out the diseased sweet potatoes. The sorting was carefully done, so as to avoid bruising as much as possible, about once a month during the storage period.

In all, seven tests, including three varieties, were made. The average storage period for all of these experiments covered 134 days. The results are given in Table 4.

TABLE 4.—*Relation of sorting to the keeping quality of sweet potatoes.*

[Shrinkage and decay averages for three varieties in seven storage-house tests in Southern States during four seasons.]

Variety.	Year.	Sorted.					Not sorted.				
		Weight at the beginning.	Time in storage.	Weight at end of storage period.	Shrinkage.	Loss due to decay.	Weight at the beginning.	Time in storage.	Weight at end of storage period.	Shrinkage.	Loss due to decay.
		Lbs.	Days.	Lbs.	Per cent.	Per cent.	Lbs.	Days.	Lbs.	Per cent.	Per cent.
Dooley	1912-13	300	125	272.4	9.2	0.93	300	125	272.79	9.30	0.74
Nancy Hall	1912-13	50	182	39.0	22.0	6.00	50	182	40.00	20.00	4.00
Dooley	1913-14	847	106	759.76	10.3	2.70	2,527	106	2,239.93	11.36	1.20
Do	1913-14	42	131	36.25	13.7	5.00	42	131	38.26	8.90	2.00
Nancy Hall	1913-14	42	125	34.57	17.7	4.40	42	125	36.67	12.70	1.11
Big-Stem Jersey ..	1914-15	36	152	32.00	11.1	8.00	36	152	32.11	10.80	2.00
Nancy Hall	1915-16	32	103	29.06	9.2	.....	29	103	26.74	7.80	.....
Total		1,349	.....	1,203.04	.....	.....	3,026	.....	2,686.50	.....	.....
Average .....		.....	132	.....	10.82	2.63	.....	132	.....	11.24	1.21

Except in one experiment with the Nancy Hall variety, the decay was greater in the sorted lots than in those not sorted. The average decay of the sorted lots was 2.63 per cent and of those unsorted 1.21 per cent. Under less careful handling there would probably have been more decay in both sorted and unsorted lots, but especially in the former. No definite explanation can be given for the larger percentage of decay in sweet potatoes that were sorted, but it is possible that slight bruising resulted from handling, and that the sorting increases the chance of spreading disease from decayed to

sound sweet potatoes. One decayed sweet potato left undisturbed might be in contact with several sound ones, all of which would eventually become diseased, but it would require considerable time for all of these to decay completely. When sorted, each of the potatoes which had become infected with disease might be placed in contact with several uninfected ones, thereby spreading the disease to them.

Since sorting increases disease injury and in addition requires considerable labor, it seems inadvisable to disturb sweet potatoes until they are to be placed on the market. Should decay appear to be serious, the potatoes should be sorted and, if the market is at all satisfactory, disposed of immediately.

COMPARISON OF THE KEEPING QUALITIES OF VARIOUS VARIETIES OF SWEET POTATOES.

Experiments were begun in 1916 to determine the shrinkage and decay in storage of the most important varieties of sweet potatoes grown in the United States. These experiments were conducted in the storage house at the Arlington Experimental Farm, Va. The sweet potatoes were placed in bushel crates in the field and hauled to the storage house. At the house they were cleaned by wiping each potato with a soft cloth. The potatoes were then placed in weighed crates, and a second weighing showed the quantity stored. Only one crate of a variety was used in these experiments, and with some varieties there was not always a full crate. During the curing period, which averaged 20 days, the temperature was maintained between 80° and 95° F. After this it was gradually reduced and maintained between 50° and 55° F. for the remainder of the storage period. The crates of potatoes were weighed once each week during the curing period and approximately once a month thereafter through the storage period. One year the weights were taken every day during the curing and once a week throughout the remainder of the storage period. As the differences from day to day during curing and from week to week throughout the storage period were rather slight, the figures given are based on the weights at the end of curing and at monthly intervals thereafter. The results for the four years 1916-17 to 1919-20, inclusive, are given in Table 5.

Table 5 shows that the average shrinkage during the curing period was 7.97 per cent. The lowest shrinkage was 6.07 per cent for the Big-Stem Jersey, and the highest 10.27 per cent for the Gold Skin. It is worth noting that these varieties belong in the same group. Excepting the Gold Skin, all the varieties in the Jersey group were low to medium in shrinkage during the curing period. Of the other important varieties, the shrinkage during the curing period was as

follows: Triumph, 6.75; Porto Rico, 7.10; Nancy Hall, 6.77; Southern Queen, 7.10; Pumpkin "Yam," 8.51; Dooley, 9.62; Red Jersey, 6.34; and Yellow Jersey, 7.11 per cent.

Shrinkage continued throughout the storage period, but was greatest during the curing period, and the rate gradually decreased to the end of storage. The shrinkage due to loss of moisture during the curing period, which averaged 20 days, was nearly half the loss for the entire storage period of 160 days.

The average loss in weight for all varieties for the entire storage period was 16.52 per cent, the lowest being 12.96 per cent for the Pierson and the highest 21.01 per cent for the Gold Skin variety. The heavy loss in the latter was caused largely by the drying of decayed potatoes. The sweet potatoes in this experiment were in storage for a longer period than is usual in commercial houses. In fact, the average storage period for sweet potatoes is probably not more than three months, since marketing usually begins soon after the potatoes are stored and continues until all are removed. Very few sweet potatoes remain in storage longer than four months, so that the 113-day period is more nearly comparable to commercial storage than 160 days.

TABLE 5.—*Relation of variety to the keeping quality of sweet potatoes stored in crates.*

[Shrinkage and decay averages in storage-house tests during four seasons.]

Variety.	Average weight of potatoes at harvest time.		Shrinkage during curing, 20 days.	Shrinkage at end of—					Loss due to decay for 160 days.
				50 days.	83 days.	113 days.	142½ days.	160 days.	
	Pounds.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
White Sealy ¹	36.81	7.03	8.15	9.67	10.87	11.98	13.15	.....	.....
Belmont.....	34.61	8.44	10.57	12.05	13.41	15.00	16.44	.....	1.08
Georgia (old-time "yam")...	36.92	8.80	10.83	12.62	14.52	15.58	17.63	.....	.32
Yellow "Yam".....	45.44	7.57	10.50	12.28	14.15	15.74	16.81	.....	.11
Vineless Pumpkin "Yam" ² ..	45.95	7.05	9.10	10.86	12.58	14.49	15.58	.....	.35
Pierson.....	46.91	7.08	8.37	9.83	10.98	12.13	12.96	.....	.....
Yellow Strasburg.....	48.00	7.06	9.08	11.06	12.37	13.42	14.46	.....	.02
Triumph.....	43.23	6.75	8.28	9.60	11.38	12.40	12.98	.....	.25
Haiti.....	45.34	6.81	11.80	13.98	16.01	17.73	18.64	.....	2.45
Red Bermuda.....	50.25	7.64	9.73	11.36	12.84	14.31	15.24	.....	.72
Red Brazil.....	49.50	7.98	10.38	12.24	14.08	15.55	16.89	.....	2.18
Key West.....	40.73	9.43	11.12	12.74	14.66	17.01	17.75	.....	.38
Porto Rico.....	44.53	7.10	8.87	11.05	13.09	14.24	15.29	.....	.13
Creola.....	31.94	7.89	9.46	10.92	12.15	13.65	15.47	.....	.19
Dahomey.....	40.41	7.55	9.11	10.34	11.51	12.69	13.73	.....	.07
Florida.....	48.34	7.34	9.33	10.98	12.47	13.90	14.87	.....	1.39
General Grant Vineless.....	46.39	7.50	9.59	11.25	13.00	14.49	15.43	.....	.....
Nancy Hall.....	45.23	6.77	8.31	9.73	11.43	12.53	13.60	.....	.....
White "Yam".....	47.03	7.80	9.44	10.99	12.59	13.93	14.88	.....	.40
Southern Queen.....	44.78	7.10	8.84	10.38	11.89	13.03	14.09	.....	.02
Pumpkin "Yam".....	43.94	8.51	11.17	13.27	15.59	17.32	18.57	.....	2.64
Norton.....	31.62	8.73	13.35	15.50	18.37	19.26	20.46	.....	1.58
Dooley.....	41.59	9.62	12.36	14.11	16.49	18.22	19.86	.....	.34
Red Jersey.....	41.64	6.34	7.80	9.46	11.45	12.68	14.75	.....	.14
Big-Stem Jersey.....	47.97	6.07	8.06	10.11	11.90	13.51	14.43	.....	3.65
Yellow Jersey ¹	45.15	7.11	8.57	10.19	12.03	13.49	14.88	.....	1.37
Gold Skin ²	44.02	10.27	12.88	14.99	17.56	19.45	21.01	.....	8.66
Average for all varieties..	43.27	7.97	10.20	11.99	13.82	15.31	16.52	.....	1.10

¹ Average for only two years.

² Average for only three years.

The loss due to decay in this experiment was very small, the average being only 1.10 per cent for all varieties. Among the varieties tested, those showing the greatest loss were the Gold Skin, 8.66; Big-Stem Jersey, 3.65; Pumpkin "Yam," 2.64; Haiti, 2.45; and Red Brazil, 2.18 per cent. Of the 27 varieties in the experiment 4 showed no decay; 7 varieties had a loss between 0.02 and 0.25 per cent; 6 varieties between 0.25 and 0.50 per cent; 1 variety 0.72 per cent; 4 varieties between 1 and 2 per cent, and the others showed losses between 2.18 and 8.66 per cent.

The conditions in the storage room were nearly ideal; therefore the loss due to decay was so slight that differences between varieties mean very little.

Several varieties, chiefly those belonging to the Jersey group, namely, Red Jersey, Big-Stem Jersey, Yellow Jersey, and Gold Skin, though not showing excessive decay, had begun to deteriorate and from a commercial point of view should have been removed sooner.

COMPARISON OF THE KEEPING QUALITIES OF SWEET POTATOES WHEN STORED AT DIFFERENT TEMPERATURES.

To determine the effects of different temperatures on the keeping qualities of sweet potatoes, experiments were conducted during 1917-18 and 1918-19. Three standard varieties of sweet potatoes were stored in each of three different rooms, where after the curing period it was the plan to maintain the temperature between 50° and 55° F., 55° and 60° F., and 60° and 65° F., respectively. The aim during curing was to keep the temperature high enough to cure the potatoes properly, all three rooms being treated alike. After the curing period the temperature was gradually lowered in each room and an effort made to maintain it between the points mentioned. The average weekly temperature usually varied only a few degrees, as shown in figure 1.

The shrinkage of sweet potatoes at the end of the curing period and at various intervals during storage and the percentage of loss due to decay are shown in Table 6.

Table 6 shows that under all temperatures about half the shrinkage occurred during the curing period. After the curing period the shrinkage continues, but the rate is rather slow, averaging less than 1½ per cent a month under the three sets of temperatures. Comparing the average percentage of shrinkage under the three different temperatures, it is seen that it is greater at the higher temperatures. The difference between the first two sets is especially noticeable, and is just as noticeable with the Big-Stem Jersey and Nancy Hall varieties in the third set. The Southern Queen showed less shrinkage at 60° to 65° F. than at any other temperature. The average total shrinkage of

the three varieties for the storage period of 164 days was 13.83 per cent when stored at 50° to 55° F., 15.27 per cent at 55° to 60° F., and 15.70 per cent at 60° to 65° F. These percentages are fairly low for such a long storage period, especially for storage in crates. At 111 days in this experiment, this period being comparable to the time sweet potatoes are ordinarily held in storage, the average percentage of shrinkage was 11.33 at 50° to 55° F., 12.47 at 55° to 60° F., and 13.22 at 60° to 65° F.

TABLE 6.—*Relation of temperature during storage of the keeping quality of sweet potatoes.*

[Shrinkage and decay averages of three standard varieties in storage-house tests during two seasons.]

Variety.	Temper- ature.	Weight ¹ at har- vest time.	Loss in weight dur- ing cur- ing.	Loss in weight at end of—						Loss due to decay in 164 days.	
				51 days.	82 days.	111 days.	141 days.	164 days.			
	° F.	Lbs.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.
Big-Stem Jersey.....	50 to 55	142.56	6.59	8.02	9.42	10.88	12.09	19.31	13.54	1.81	1.27
Nancy Hall.....	50 to 55	140.00	7.14	8.46	9.69	11.03	12.12	18.44	13.10	.84	.60
Southern Queen.....	50 to 55	153.09	7.83	9.12	10.49	12.00	13.21	22.50	14.69	.59	.38
Total for three varieties.....		435.67						60.25		3.25	
Average for three varie- ties.....			7.23	8.55	9.88	11.33	12.49		13.83		.75
Big-Stem Jersey.....	55 to 60	144.16	7.74	9.02	10.82	12.59	14.24	22.50	15.61	1.69	1.17
Nancy Hall.....	55 to 60	144.47	8.50	9.73	11.12	12.74	14.30	22.31	15.45	.72	.49
Southern Queen.....	55 to 60	151.72	8.71	9.68	11.53	12.09	14.03	22.44	14.79	.56	.37
Total for three varieties.....		440.34						67.25		2.97	
Average for three varie- ties.....			8.32	9.48	11.16	12.47	14.18		15.27		.67
Big-Stem Jersey.....	60 to 65	139.94	7.98	9.60	12.10	13.75	15.46	23.62	16.85	3.31	2.36
Nancy Hall.....	60 to 65	143.16	9.17	11.05	13.18	14.69	15.89	24.12	16.85	.78	.54
Southern Queen.....	60 to 65	150.53	6.73	8.24	10.40	11.73	12.81	20.34	13.51		
Total for three varieties.....		433.62						68.09		4.09	
Average for three varie- ties.....			7.93	9.61	11.87	13.22	14.68		15.70		.96

¹ Weight means the average weight of potatoes stored per year (total weight divided by 2).

Toward the end of the storage period the Big-Stem Jersey usually withers at the tips, while the two other varieties remain plump. The Southern Queen retains its plumpness better than the others. For this reason Jersey varieties are usually marketed first.

KEEPING QUALITIES OF SWEET POTATOES STORED IN BINS AND IN CRATES.

Sweet potatoes may be stored in bins, or in crates, boxes, hampers, baskets, or other containers. It is often asserted that crates, baskets, and other containers are better than bins, because when decay sets in it is likely to be confined to the container holding only a small quan-

tity; but in bins the decay is likely to spread throughout the large bulk of the potatoes. It is asserted also that less injury occurs in handling where small containers are used, because the potatoes are placed in the receptacles in the field and are not disturbed until prepared for market; but when stored in bins the potatoes are gathered in baskets and dumped into bins, and some bruising will occur even with the most careful workers. In ordinary commercial handling there is considerable bruising.

Experiments were begun in 1917 to study the shrinkage and decay in three standard varieties of sweet potatoes stored in 1-bushel crates and in bins. The bins used were about 4 feet wide, 8 feet long, and 7 feet high, although the potatoes were seldom more than 5 feet deep in the bins. After the potatoes were plowed out they were placed in 1-bushel crates and hauled directly to the storage house. Those put in bins were first cleaned and weighed. The potatoes intended for the crate experiments were cleaned and placed in weighed crates, and the total weight was then recorded. The crates were not disturbed until the end of the storage season. In the room where these experiments were conducted the temperature was maintained between 55° and 60° F. The average temperature in this room is shown in figure 1.

Table 7 presents the results of these experiments for 1917-18 and for 1918-19.

TABLE 7.—*Relation of the storage receptacle to the keeping quality of sweet potatoes.*

[Shrinkage and decay averages of three standard varieties stored in bins and in crates during two seasons.]

Variety.	Storage receptacle.	Time in storage.	Average weight at—		Loss in weight due to shrinkage.		Loss in weight due to decay.	
			Harvest time.	End of storage period.				
		Days.	Pounds.	Pounds.	Pounds.	Per cent.	Pounds.	Per cent.
Big-Stem Jersey.....	{Bin.....	171½	3,000.90	2,586.59	414.31	13.80	65.59	2.18
	{Crate.....	154	144.16	121.66	22.50	15.61	1.69	1.17
Nancy Hall ¹	{Bin.....	172	3,970.56	3,506.69	463.87	11.18	19.94	.50
	{Crate.....	162	131.94	117.00	14.94	11.32	.19	.14
Southern Queen.....	{Bin.....	171½	2,930.75	2,533.59	397.15	13.55	13.53	.48
	{Crate.....	154	151.72	129.28	22.44	14.79	.56	.37
Average for three varieties.	{Bin.....	171½	9,902.22	8,626.87	1,275.34	12.88	99.06	1.00
	{Crate.....	156½	427.81	367.94	59.87	14.02	2.47	.57

¹ Only one year, 1918-19.

Table 7 shows that the average shrinkage for the three varieties was greater in crates than in bins, although the difference was not as great as is commonly supposed. The average percentage of decay was a little greater in the bins than in the crates, although it was so slight that the difference is not of great importance. Under less favorable conditions the differences might be greater.

The sweet potatoes in the bins were kept longer than those in crates. If the latter had been kept the full length of time (171½ days) the shrinkage would have been a little greater, since during the last month of storage the average shrinkage of the three varieties at 55° to 60° F. was a little more than 1 per cent, as shown in Table 6. The results with the Nancy Hall are for one year only, since

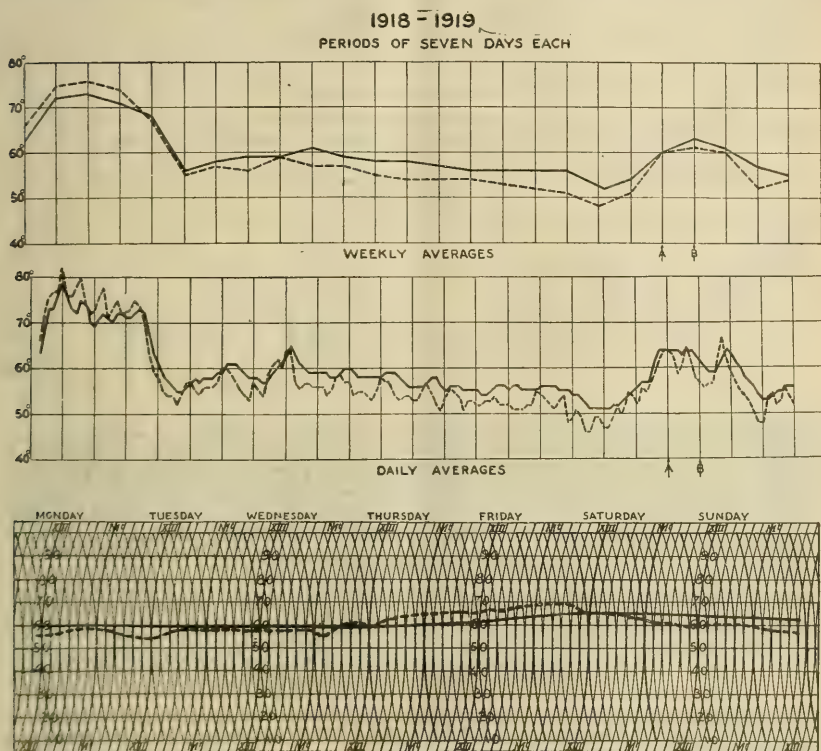


FIG. 3.—Diagrams showing the temperature in the interior of the bins (solid lines) as compared to the temperature of the air (broken lines) in 1918-19 at the Arlington Experimental Farm, Va. The upper diagram gives the average temperature for the storage season, by weekly periods. The middle diagram gives the same data by daily averages. In these diagrams each square indicates a period of seven days. The lower diagram is a typical thermograph sheet, in this case for the period A-B.

there was no bin test of this variety in 1917-18. The shrinkage of this variety was low in both the bins and crates in 1918-19.

RELATION OF THE TEMPERATURE IN THE BINS TO THE TEMPERATURE OF THE SURROUNDING AIR.

Air-soil thermographs were employed to ascertain the differences, if any, between the temperature in the center of the bins and the temperature of the air in the storage house. Figures 3 and 4 show

the temperatures in the bins and of the air recorded by the instruments and averaged by 2-hour periods for the years 1918-19 and 1919-20, respectively. The variety used was the Southern Queen, and the bin contained about 75 bushels each year. The average temperature in the bins was somewhat higher than that of the air, and the fluctuations in temperature were less marked in

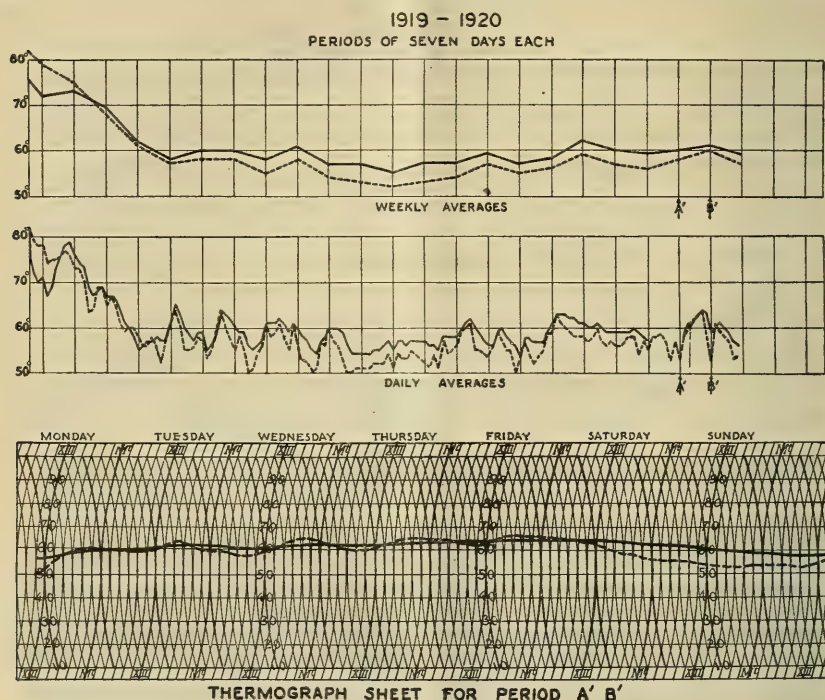


FIG. 4.—Diagrams showing the temperature in the interior of the bins (solid lines) as compared to the temperature of the air (broken lines) in 1919-20 at the Arlington Experimental Farm, Va. The upper diagram gives the average temperature for the storage season, by weekly periods. The middle diagram gives the same data by daily averages. In these diagrams each square indicates a period of seven days. The lower diagram is a typical thermograph sheet, in this case for the period A'-B'.

the bins than in the air. Some work was done in studying the temperature of the bins as compared with that of standard bushel crates, but owing to its incompleteness the results are not presented here. In general, the temperature in the crates was about the same as that of the surrounding air and somewhat lower than the temperature of the interior of the bins.

COMPARISON OF THE KEEPING QUALITIES OF FOUR IMPORTANT COMMERCIAL VARIETIES OF SWEET POTATOES STORED UNDER LIKE CONDITIONS.

Experiments were begun in 1917 to determine the relative keeping qualities of the more important commercial varieties of sweet potatoes. The Southern Queen, Nancy Hall, Big-Stem Jersey, and Porto Rico varieties were used in this experiment, and the purpose of the workers was to store these in bins in sufficiently large quantities to be comparable with commercial conditions. (Table 8.)

TABLE 8.—*Comparison of the keeping qualities of four standard varieties of sweet potatoes stored in bins.*

[Shrinkage and decay averages at a temperature of 50° to 55° F. during four seasons.]

Variety and year.	Room No.	Weight at—		Loss in weight.	Shrinkage.	Weight of decayed potatoes.	Decay.	Time in storage.
		Harvest time.	End of storage period.					
Southern Queen:		<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Days.</i>
1917-18.....	3	2,512.50	2,119.37	393.12	15.65	20.56	0.82	171
1918-19.....	3	3,349.00	2,947.81	401.19	11.98	6.50	.19	172
1919-20.....	3	2,217.81	1,984.75	233.06	10.51	8.94	.40	159
1920-21.....	3	1,498.75	1,397.25	101.50	6.77	2.00	.13	164
Total.....		9,578.06	8,449.19	1,128.87		38.00		
Average.....					11.79		.40	166½
Nancy Hall: ¹								
1918-19.....	3	3,970.56	3,506.69	463.87	11.69	19.94	.50	172
1919-20.....	3	1,657.62	1,528.37	129.25	7.80	13.25	.80	159
1920-21.....	3	1,498.50	1,407.12	96.37	6.43	11.75	.79	165
Total.....		7,126.69	6,442.19	689.50		44.94		
Average.....					9.67		.63	165½
Big-Stem Jersey:								
1917-18.....	3	1,931.50	1,699.50	232.00	12.01	91.94	4.76	171
1918-19.....	3	4,070.31	3,473.69	596.62	14.66	39.25	.96	172
1919-20.....	3	2,533.44	2,175.25	358.19	14.14	87.31	3.05	159
1920-21.....	3	1,498.25	1,384.50	113.75	7.59	1.50	.10	165
Total.....		10,033.50	8,736.94	1,300.56		220.00		
Average.....					12.96		2.19	166½
Porto Rico: ²								
1919-20.....	3	2,429.06	2,111.31	317.75	13.08	18.00	.85	151
1920-21.....	3	1,497.50	1,336.50	161.00	11.42	5.25	3.50	166
Total.....		3,726.56	3,447.81	478.75		23.25		
Average.....					12.82		.62	158½

¹ Results for three years only.

² Results for two years only.

For the Southern Queen the average storage period was 161½ days, the average shrinkage 11.79 per cent, and the average decay 0.40 per cent. The figures for the Nancy Hall are for three years only and show an average shrinkage of 9.67 per cent and 0.63 per cent decay for the average storage period of 165½ days. The work on the Big-Stem Jersey was carried on for four years and showed 12.96 per cent

shrinkage and 2.19 per cent decay for the storage period of 166 $\frac{3}{4}$ days. The results with the Porto Rico variety for two years showed 12.82 per cent shrinkage, with 0.62 per cent decay for the storage period of 158 $\frac{1}{2}$ days.

SUMMARY.

With careful handling it is possible to store and keep sweet potatoes for four months with losses as low as 7.52 per cent from shrinkage and decay. With ordinary commercial handling these losses ran as high as 20.40 per cent and averaged 10 per cent. (See Table 1.)

Sweet potatoes stored in houses lost from 0.5 per cent to 2 per cent from decay, while like sorts stored in banks and pits showed a loss of from 4 to 40 per cent. (See Table 2.)

Sweet potatoes injured in harvesting and handling lost 28.13 per cent by shrinkage, and stock that was carefully handled lost 13.83 per cent. (See Table 3.)

Sweet potatoes sorted from time to time during the storage period showed greater losses from decay than those not sorted. (See Table 4.)

Storage tests with single crates of each of all the important varieties of sweet potatoes showed that the shrinkage during the curing period varied from 6.07 to 10.27 per cent. The average loss in weight for all varieties for the storage period was 16.52 per cent, the lowest being 12.96 per cent and the highest 21.01 per cent. (See Table 5.)

Sweet potatoes stored at 50° to 55° F. lost 13.83 per cent in weight; those stored at 55° to 60° F. lost 15.27 per cent, and those stored at 60° to 65° F. lost 15.70 per cent. (See Table 6.)

In these experiments sweet potatoes of the Nancy Hall, Southern Queen, and Big-Stem Jersey varieties stored in crates showed greater shrinkage than similar stock stored in bins. (See Table 7.)

The average temperature in bins filled with sweet potatoes is higher than that of the surrounding air. (See figs. 3 and 4.)

When stored in bins under uniform conditions the Southern Queen variety showed the least decay, the Porto Rico and Nancy Hall were about equal, and the Big-Stem Jersey decayed most of any of these four varieties. In shrinkage the Nancy Hall was lowest, the Southern Queen next, the Porto Rico next, and the Big-Stem Jersey was highest. (See Table 8.)

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1064



Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C.

August 21, 1922

OLEORESIN PRODUCTION: A MICROSCOPIC STUDY OF THE EFFECTS PRODUCED ON THE WOODY TISSUES OF SOUTHERN PINES BY DIFFERENT METHODS OF TURPENTINING.

By ELOISE GERRY, *Microscopist, Forest Products Laboratory, Madison, Wis.*

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THE NAVAL STORES INDUSTRY.

Naval stores is the name applied to the products obtained chiefly by distilling the oleoresin or gum which exudes from living pines when the wood is wounded. The turpentine and rosin thus obtained

ACKNOWLEDGMENTS.

The writer wishes to express her appreciation of the many courtesies extended to her at the places visited in Mississippi, Louisiana, and Florida, and particularly to the following for assistance given in obtaining specimens and information on methods and practices:

The Bogalusa Turpentine Co., especially to Messrs. Adams, Kemp, A. T. Lewis, C. C. Harding, and N. T. Dorsey; Mr. J. P. Frain, of the Fernwood Lumber Co., Fernwood, Miss.; Mr. J. F. Payne, Gulfport, Miss.; Mr. J. A. Taylor, of the Gillican-Chipley Co., the Union Naval Stores Co., the Imperial Naval Stores Co., Poitevent & Favre, all of New Orleans, La.; the Consolidated Naval Stores Co., of Jacksonville, Fla., especially Mr. McGarvey Cline; Mr. G. A. Clark, of Daytona; Mr. D. N. Corbett, of Orlando; Mr. A. Sessoms; and Mr. W. A. Sessoms, of Bonifay, Fla. Assistance was also generously given by the organization of the Florida National Forest, especially Capt. I. F. Eldredge, Supervisor L. L. Bishop, Deputy Supervisor E. R. McKee; also by Mr. Johnson and Mr. W. N. Hartgrove, of Garniers, Fla.; by Mr. Austin Cary, of the Washington office of the Forest Service; and by Mr. R. L. Pettigrew, Dr. A. W. Schorger, and Mr. H. F. Wiess, all formerly of the Forest Products Laboratory staff.

Helpful criticisms and suggestions were also given by Dr. C. H. Herty, editor of the *Journal of Industrial and Engineering Chemistry*, and by Prof. C. E. Allen and Prof. J. B. Overton, of the department of botany of the University of Wisconsin, as well as by members of the staff of the Forest Products Laboratory.

have to-day supplanted pitch and tar, the chief products of this industry in colonial times in the United States.¹ But the descriptive name, naval stores, given when these commodities were used extensively in the construction and maintenance of sailing vessels, still persists. That mankind has long made use of these forest products appears from the descriptions of the production and uses of pitch contained in ancient writings.² As long ago as the fifth century before Christ, the pines of Macedon were a famous source of pitch. During the period 315 to 166 B. C., Macedon is recorded to have had a distinct monopoly of wood and pitch, which highly valued and important commodities could not be exported without special permission from the ruler.³ Pitch was obtained by destructive distillation of the heartwood or of especially pitchy chips from wounded trees, or by driving off the water from the exuded gum. Pitch was in great demand for calking the seams of ships, including the war ships of the period, as is related in the case of the "wooden walls of Athens at Salamis." It was also used, for example, as a surface coating for altars and doors or as a sizing or lining for clay storage jars, used as containers for grain and other supplies.

Until rather recently many of the methods used in the early days of the industry in this country were still in vogue. The cup method, introduced on a commercial scale about 1904,⁴ has, however, of late largely supplanted the wasteful box system. (See Pl. I, fig. 1.) Another much-needed improvement is seen in the tendency to reduce the amount of wood removed when the trees are scarified or chipped. The success of this practice has been demonstrated by experiments and the experience of progressive operators. In order to determine the best methods of turpentine, a comprehensive understanding of the tree's responses must be obtained. This involves thorough research of problems bearing on many aspects.

PURPOSE OF THE INVESTIGATION.

The investigation here described is concerned primarily with the comparison of the results of experiments with three different methods of chipping. It is shown that the success of a method can not be judged merely on the basis of the yield obtained. The maintenance of wood production, as indicated by growth in height and in diam-

¹ Public Record Office, London, 1610. "Instructions for suche things as are to be sente from Virginia." Also "Booke of the Commodities of Virginia" (cited from U. S. Dept. Agr. Bul. 229.)

² Theophrastus: "Enquiry into Plants" III, IX, 1-3 and IX, II & III. Plini: *Naturalis Historia* XVI.

³ Glotz, G.: "L'Histoire de Délos d'après les Prix d'une Denrée." *Revue des Études Grecques*, Tome XXIX. Juillet-Septembre, 1916. (Reviewed by Gerry, E. Jour. For. 19: April, 1921, p. 438.)

⁴ Herty, C. H.: "The Turpentine Industry of the Southern States." Jour. Franklin Institute. March, 1916.

eter, and the preservation of the general health of the tree are considerations of fundamental importance. This is especially true with reference to the methods that are to be used in the future for turpentineing smaller, second-growth trees. The need for wider knowledge and the practice of better methods is imperative in the United States, in order that this important and exceptional opportunity for the production of naval stores shall not be wiped out or wasted by improper exploitation.⁵

The work covered was undertaken in order to obtain, by means of microscopic study, information on the changes which result from turpentineing in the wood of the pines, which are the chief sources of naval stores. The advantages and disadvantages of different methods of operation were determined chiefly by examining specimens of the wood produced near the faces or scars. These specimens were usually cut just above the streak or surface of the last wound. Structures found on workings of different ages were also studied. The specimens furnished evidence which served as a check of considerable precision upon the more general means of comparison, such as amount of gum produced and percentages of dead and dry-faced trees caused by turpentineing. Changes produced by turpentineing which were registered in the internal anatomy of the pines were studied, not only in the completed annual ring at the end of the season, but also particularly in specimens obtained periodically throughout the year. The first material was cut before wood formation began in the spring, and the development shown in fresh specimens cut each month thereafter was studied throughout the subsequent growing season. The chief source of material was a cooperative experiment carried on at Columbia, Miss., where three methods of chipping were compared,⁶ but specimens were also collected at other points in Mississippi and in Louisiana and Florida.

An attempt was also made to determine the significance of certain observations made at the Forest Products Laboratory not in accord with views previously published, some of which were founded upon analogy rather than upon the study of native American species.⁷

OLEORESIN.

The exudation obtained by the systematic scarification of the living pines, especially longleaf pine in the United States, is variously known as "oleoresin," "gum," "dip," and "scrape" (when hardened after long exposure to the air). From this substance rosin

⁵ Approximately 75 per cent of the world's supply of gum turpentine is made in the United States.

⁶ See pp. 12 to 25.

⁷ Herty, C. H., "Relation of Light Chipping to the Commercial Yield of Naval Stores," For. Ser. Bul. 90, 1911. Tschirch, A., "Die Harze u. d. Harzbehälter," 1900.

and turpentine are obtained as the products of distillation. The "gum turpentine" distilled from oleoresin is distinguished from "wood turpentine," which is obtained from the steam or destructive distillation of the resinous heartwood of stumps or dead or down timber.

Fresh gum spirits of turpentine distilled from the southern pines of the United States consists of several similar or closely related compounds known as terpenes, together with small and varying quantities of oxidized derivatives thereof.⁸ The empirical formula of the terpenes is $C_{10}H_{16}$, indicating that turpentine consists almost entirely of carbon and hydrogen. Of the terpenes, the one known as pinene occurs in the highest proportion in spirits of turpentine. Alpha pinene is found to the extent of 80 to 85 per cent in the average pure, fresh, American gum spirits of turpentine. Among the other terpenes which have been found in small quantities in turpentine oil may be mentioned beta pinene, camphene, silvestrene, and dipentene, the last two being found also in destructively distilled wood turpentine. American pinene, the greater part of which is obtained from longleaf pine (*Pinus palustris*) gum, has optical properties different from those of the French. The pinene from slash pine (*Pinus caribaea*), however, resembles the French in this particular. Otherwise the turpentine oils of slash and longleaf pines are very similar, whether obtained from the wood or from the leaves.⁹

STRUCTURE OF WOOD OF TURPENTINE PINES.

Of fundamental significance for the understanding of the production of naval stores is the structure of the wood of the pine, especially of *Pinus palustris* Mill. (longleaf pine), and *Pinus caribaea* Morelet (slash pine), which are the chief turpentine pines of the southern United States and produce approximately 75 per cent of the world's supply of naval stores.¹⁰ It is from the outer wood next the bark in the living pine that oleoresin is obtained. Here also the responses to turpentinizing, differing according to the methods practiced, are clearly registered in the woody tissue that is formed after the scarifications have been made.

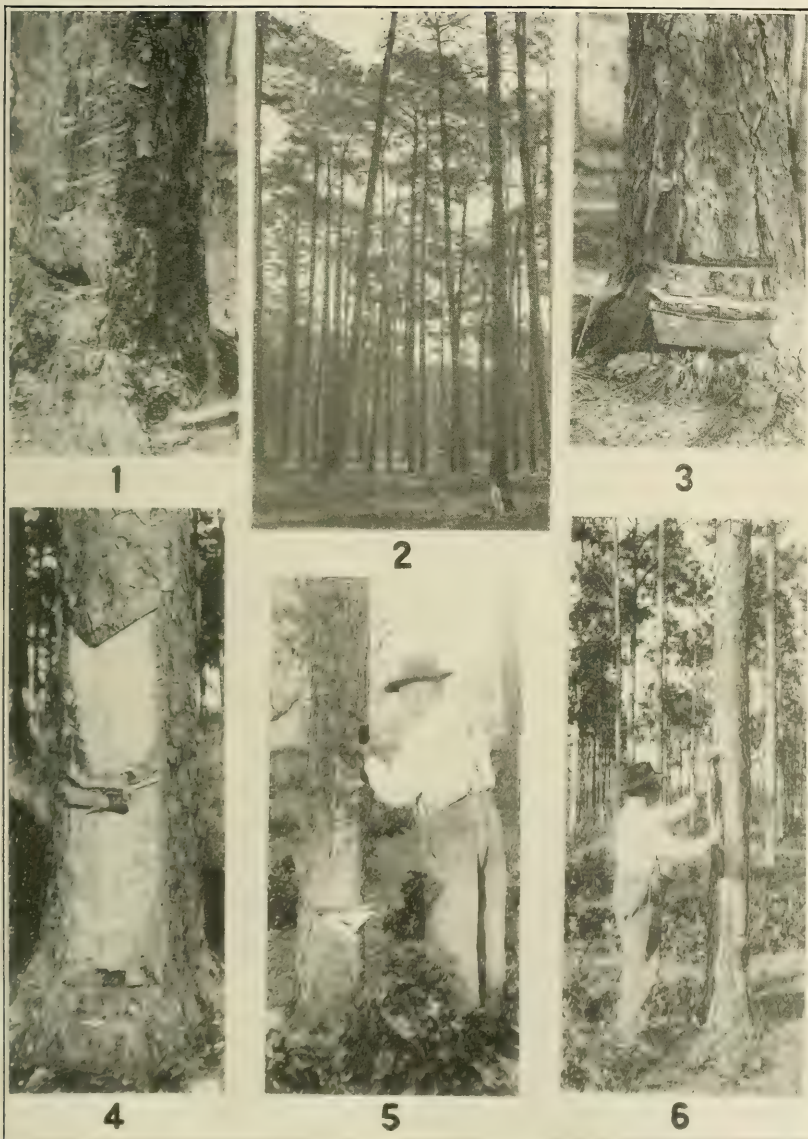
⁸ Veitch, F. P., and V. E. Grottlisch, "Turpentine," U. S. Dept. Agr. Bul. 898, 1920.

⁹ Schorger, A. W., "Contribution to the Chemistry of American Conifers." Trans. Wis. Acad. of Sci. Arts and Letters, 19: March, 1919, p. 742.

¹⁰ Oleoresin is also obtained in relatively small quantities from various other species of pine, including: In the United States, *P. echinata*, shortleaf; *P. taeda*, loblolly; *P. ponderosa*, western yellow; and *P. serotina*, pond pine; in France, *P. pinaster* or *maritima*, maritime pine; in Greece and Algeria, *P. halepensis*, Aleppo pine; in Italy, *P. pinea*, stone pine; in Austria, *P. laricio*, *austriaca*, or *nigra*, black pine; in India, *P. longifolia*, chir pine; and *P. excelsa*, the Himalayan or Bhotan pine; in Mexico and Central America, *P. ayacahuite*, the Mexican white pine; in central Germany, Poland, and northern Russia, *P. silvestris*, Scotch pine; and in Japan, *P. thunbergii*, Japanese black pine. (From U. S. Dept. Agr. Bul. 898.)

PLATE I

- FIG. 1.—The old method of cutting a box or cavity in the butt of the tree. Disadvantages: The tree was weakened; it became a fire hazard; the box was difficult to empty; and wasteful as a receptacle for receiving gum from a high face.
- FIG. 2.—Stand which includes the trees selected from the narrow, double, and standard chipped tracts at Columbia, Miss., for detailed microscopic study throughout the respective seasons of 1916 and 1917. Note the presence of some suppressed trees.
- FIG. 3.—The American practice of placing an "advance streak" some weeks before regular chipping begins. (This picture was obtained through the courtesy of Mr. F. Canuing of the Forest Service of India.)
- FIG. 4.—Appearance of a tree at the end of a standard 2-year commercial operation, at Columbia, Miss.
- FIG. 5.—Small or modified American face used experimentally on small timber on the Florida National Forest after 3 years' turpentineing.
- FIG. 6.—French method of turpentineing as practiced experimentally on small timber on the Florida National Forest after 3 years' turpentineing. Note shape of face, chipping tool, and area freshened.



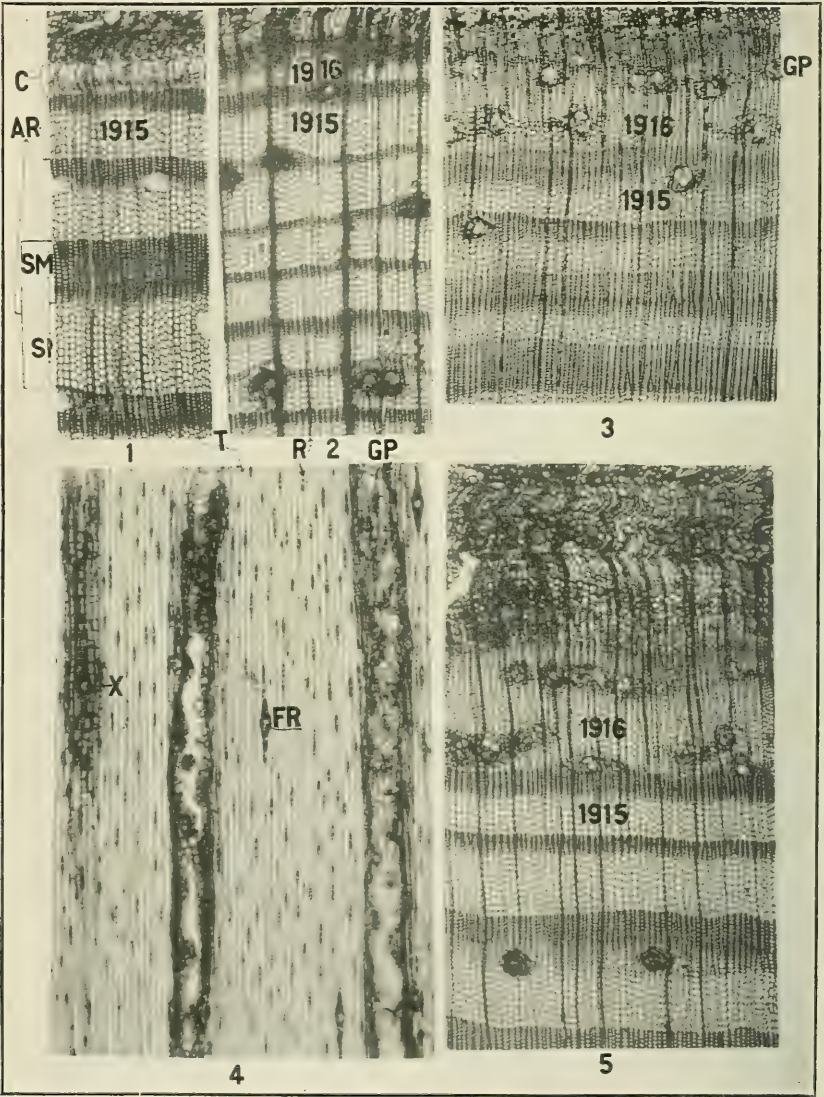


PLATE II

In these specimens from a virgin or first-year operation at Columbia, Miss., 1916, the bark appears at the top of the figure in all except figure 4. The 1916 ring or its incipient formation is shown next the bark. All the other rings shown were formed by the trees before turpentine began.

AR, annual ring; SP, spring wood; SM, summer wood; T, tracheids or wood fibers; R, rays; and GP, groups of parenchyma cells or resin passages.

FIG. 1.—An example of the condition of the tree on April 13, 1916. No wood or resiniferous tissue had fully differentiated, but cambial activity (preliminary stages of wood formation) is apparent (at C) next the bark.

FIG. 2.—By June 13, 1916, at least 5 or 6 tracheids are apparent, and resiniferous tissue appears to be about to differentiate. In the first year several rows of wood cells usually formed before resin passages were produced.

FIG. 3.—Specimen cut July 5, 1916. Numerous resin passages present developed early in the annual ring. Compare size of passages in the 1916 ring with size of those in the other rings.

FIG. 4.—Tangential section through 1916 ring, showing longitudinal view of vertical resin passages (GP), formed in a turpentine tree. Also T, tracheids; R, ray parenchyma; FR, ray with horizontal resin passage; and X, a crossing of the vertical and horizontal resiniferous systems.

FIG. 5.—Specimen cut July 5, 1916. In the 1916 ring, forming next the bark, are tangential series including several resin passages. This very abundant formation of resin passages accompanies the wounding or turpentine. The exudation from these is shown in Plate III, figure 2.

Longleaf pine as found in the southern United States of America is the species chiefly discussed and illustrated in the following pages as the typical producer of American naval stores. Botanically, it is classed in the division of the Spermatophyta, the subdivision of the Gymnospermae, the order Coniferales, and family Pinaceae. The structure of the wood, the principal subject of this research, as seen with the aid of the microscope in an end view or cross section made from a normal unturpented specimen, is shown in Plates II, V, and VI. The yield of oleoresin, obtained when a tree is wounded, comes from the cells of the aggregates *GP*, Plate II, figures 3, 4, 5, and elsewhere.

CAMBIUM.

The cells of the wood and bark of the pine are formed by the division and differentiation of the cells of the cambium layer, which is situated between the bark and the wood (*C*, Pl. II, fig. 1). This layer is made up of thin-walled cells, which retain their power to divide and thus produce the new cells composing the yearly rings of bark and wood, respectively.¹¹

ANNUAL RINGS.

The layer of new wood formed each year on the outside of the woody core of a tree is known as an annual ring (*AR*, Pl. II, figs. 1, 2, 3, and 5.) In the pines in question it is conspicuously differentiated into two portions. The spring wood (*SP*) has thin-walled cells and large cavities, and forms early in the growing season. The summer wood (*SM*) has denser cell walls, and though it may begin to form as early as June, it generally develops in July, or, at the latest, August. The width of the annual ring and the amount and density of the summer wood formed are markedly influenced by turpentineing, and serve as indicators of the effects of the various methods used.

SAPWOOD AND HEARTWOOD.

A varying number of the outermost annual rings of wood make up the sapwood. This is usually lighter in color than the heartwood, or central portion of the tree. The water solutions of the sap circulate through the sapwood, and it is in this region that the oleoresin exudes from certain cells (parenchyma) which are characteristically active. Each year a portion of the inner sapwood ceases to function and becomes dead heartwood; as a result the thickness of heartwood increases with the tree's age, but that of the sapwood remains, with relatively small variations, approximately the same. The walls of

¹¹ It is the cambium that tears when the wood is separated from the bark cylinder in making a willow whistle.

the older cells tend to become more or less impregnated with resin as they are transformed into heartwood, which serves primarily for mechanical support. The resin in the heartwood flows out much less easily than that in the sapwood, as may be seen on any freshly cut log or stump. Although the heartwood contains more resin by chemical analysis, it will not, if tapped, produce a sustained yield of resin, as the sapwood, if properly treated, will. Gum turpentine is obtained from a number of the outermost sapwood rings (Pl. III, fig. 2). The depth of the cut in relation to the width of the sapwood is a very significant factor with reference to both the yields obtained and the injurious effect of turpentine upon the tree. Successful turpentine operations depend upon keeping the sapwood in a healthy condition, capable of responding not only to normal stimuli but to the special wound stimuli as well.

TRACHEIDS.

During the growing season, April to November, the individual cells of the outermost annual ring of the sapwood, as they are derived from the cambium, become differentiated and develop into specialized structures. These are the tracheids. (T, Pl. II, figs. 1 to 5.) They are vertically extended cells which complete their formation and lose their protoplasmic content early. They then serve for sap conduction and finally for the mechanical support of the tree. They are not directly connected with oleoresin production, although they constitute a significant part of the organic mechanism of the tree. They differ somewhat in appearance, as was stated in the discussion of spring wood and summer wood (p. 5). The character of the summer wood tracheids and also the total number of tracheids formed often serve as indicators of the vitality and responsive power of the trees under observation.

PARENCHYMA.

The parenchyma tissue found in pines may be considered under two main heads: First, the horizontally extended parenchyma cells constituting the rays (*R*, Pl. II), including the fusiform rays (*FR*, Pl. II, fig. 4) with their horizontal resin passages; second, the vertically extended parenchymatous elements, which grouped together (*GP*, Pls. II, V, and VI), form the resin-producing centers, the so-called resin passages, ducts, or canals. The parenchyma cells are characterized by the fact that they "remain alive," that is, retain their protoplasmic content and function actively for a number of years or until approximately the time when the inner rings of the sapwood change into the heartwood.

It is both from the horizontally extended fusiform rays, as exposed on a freshly cut tangential surface, and the vertically extended parenchyma aggregates, as exposed on the cross section, at the streak, that the droplets of oleoresin may be seen to exude. Large nuclei are often to be seen in these cells, as well as accumulations of starch grains. Tannin is also reported to be associated with resin formation.¹² The vertical and horizontal systems of resin-producing parenchyma are more or less united, since they frequently cross each other. The method of turpentineing which keeps these cells active and which provides suitable stimulation to insure their greatest productivity without undue injury will give the highest and best yield of oleoresin over a period of years. In the discussion in the following pages of the results from the experiments, the methods used were judged, not alone by the yield obtained, but also by the amount and type of the wood tissue produced, as indicative of the vitality and responsive power of the trees. In each case the wood tissue produced by neighboring, comparable, unturpentineed trees growing under similar environment was studied and used as a check upon the judgments formed.

METHODS OF STUDY.

COLLECTION AND TREATMENT OF MATERIAL.

The first material to be studied was in the form of fresh chips or pieces collected by the writer from the living trees and put in corked bottles. This material was examined within a few hours after cutting. Specimens shipped to the laboratory at Madison periodically during the season were handled in the same way, with the exception that sometimes moistened cotton was put in the bottles to prevent the drying out of the specimens. Later, fixing solutions were used, and the chips or increment borings were placed in the solution selected as soon as cut. These were kept for a length of time which necessarily varied with circumstances, washed with water, and stored in glycerine and alcohol. The fixatives used were: (1) Mercuric chloride, a saturated solution in 90 per cent alcohol; (2) mixture of a saturated solution in 90 per cent alcohol of mercuric chloride (3 parts) and of picric acid (1 part); (3) chrome-acetic fixative, consisting of a mixture, in 100 cubic centimeters of water, of 1 per cent glacial acetic acid and 0.7 per cent chromic acid.

¹² Haas and Hill: "Introduction to the Chemistry of Plant Products," Vol. 1, 3d Ed. 1921. pp. 195, 217. "In *Pinus* it is stated that the amount of tannin varies with that of the resin; thus in the spring it was found that as the tannin decreased in amount so the resin increased. * * * That starch frequently is contained in the same cells with tannin suggests a connection between the two and it is not impossible that the starch may contribute glucose for the constitution of the tannin. The cells surrounding the epithelium of resin ducts contain tannin and starch." Wiesner "Die Rohstoffe des Pflanzenreiches" concluded that tannin was an intermediate product in resin formation.

SECTIONING AND MOUNTING.

Relatively thin sections (10 to 48 microns) were made from the greater number of the specimens studied. For this purpose a sliding microtome of the Jung type with the Thomson modification was used. Some observations were made with a hand lens on smoothly cut surfaces. The sections to be preserved or photographed were stained with safranin (water-alcohol mixture), dehydrated with alcohol, cleared with xylol, and mounted in Canada balsam. Microscopic examinations were also made of microtome or hand sections temporarily mounted in glycerine alcohol (50-50 mixture).

AMOUNT OF MATERIAL.

Samples were obtained each month during the 1916 and 1917 seasons, from 15 trees, 5 from each of the three experimental plots.¹³ Specimens were also examined at the end of each season from 50 trees on each plot and from 50 unturpented trees from the same locality. In addition to this, considerable material was collected from Bogalusa, La.; Kokomo and Gulfport, Miss.; Daytona, Bonifay, and the Forest Service experiments and leases near Camp Pinchot, Fla. More than 4,500 microscopic mounts were prepared and examined.

PROCESS OF TURPENTINING.

METHODS OF WOUNDING OR SCARIFYING THE TREES.

In ordinary methods of turpentineing the oleoresin is made to flow from the tree by periodically cutting a wound or streak through the bark and for a variable distance into the sapwood. In the United States the cut or streak is generally made in the form of a somewhat flattened V, the point or peak of which is at the center of the face. (Pl. I, fig. 4.) The wound used by the French is different in shape (Pl. I, fig. 6), and smaller. The Germans recently have been practicing modifications of the American system.

Except for the general type of face used, the commercial practice of turpentineing is not standardized in the United States. The size of the faces used, the amount of bark bars between faces, and the dimensions of the streak or wound cut each week, show marked differences in different operations. The depth of the weekly chipping may vary from one-half inch to 1½ inches (bark not included), and the height of the chipping from one-half inch to 1 inch, or enough, as some operators say, to "keep ahead of the lightwood."¹⁴

¹³ When more than one face was on a tree each face was indicated by a letter descriptive of its general position with reference to points of the compass, as N., S., E., W. (See, for instance, tree 1, fig. 1.)

¹⁴ See p. 31.

It is customary to cut from 28 to 40 streaks each season. Often one-third of the trees in a commercial operation die, chiefly because of the undue severity of the methods used in turpentineing. In some places the old method of cutting boxes or cavities at the butts of the trees (Pl. I, fig. 1) to hold the exuding gum, is still used, although, for the most part, cups of various types are employed (Pl. I, figs. 1, 3, 5, and 6).

After chipping, the gum or oleoresin exudes from the freshly cut surface. The most abundant exudation (88 per cent) has been observed to occur during the first three days after chipping. (Table 1.)

TABLE 1.—*Rate of exudation of gum from chipped longleaf pine.*¹

Day.	Grams of gum.	Total exudation, per cent.
First.....	113.0	67.26
Second.....	22.5	13.39
Third.....	13.5	8.04
Fourth.....	9.0	5.36
Fifth and sixth.....	9.0	5.36
Seventh.....	1.0	.59
Total.....	168.0 (=0.37 lb.)	100.00

¹ For. Serv. Bul. 90, p. 6.

SIGNIFICANCE OF RESIN PASSAGES PRESENT IN THE UNTURPENTINED TREES.

The gum which exudes during the first weeks of a virgin or first-year operation comes from the normal resin passages which were already present in the round or unturpentineed timber. Plate II, figure 1, shows the characteristic condition of the trees at Columbia, Miss., on April 13, 1916. At that time no new wood or resiniferous tissue for the 1916 ring had formed. Plate II, figure 2, shows a cross section cut from a tree on June 13, 1916. The development of new wood cells is apparent, and new resiniferous tissue may be seen to be differentiating in the region next the cambium. Plate II, figure 3, shows a cross section cut from a tree on July 5, 1916. Marked differences between individual trees occurred, however, and the range of development of the 1916 ring shown in the three figures might be encountered in material cut at the same time from different trees during either late May or early June. Often it is the end of May before the new and augmented development of the resiniferous tissue, formed after wounding in the new wood, is sufficiently advanced to yield appreciable amounts of resin. Indeed it frequently happens that in a virgin operation the normal resin passages present in the round timber may fill the cups not only for the first but also for the second and sometimes for the third time, or "dipping," before any new resin

passages are differentiated in the annual ring beginning to form for that year. An instance of a yield obtained by the end of April, ranging from 16 to 24 barrels of gum per month, per 10,000 cups, or "crop," was observed on a virgin operation where at the time no new resiniferous tissue had been formed. *Therefore it is apparent that the resin passages already present in the outer sapwood of the round timber play a significant part in producing the gum obtained.*

USE OF THE "ADVANCE STREAK."

A practice, the consequences of which are as yet not fully explained, but which appears to produce desirable results, is that of cutting a streak or wound some time before regular chipping begins.¹⁵ The results of such scarification were pointed out by Dr. C. H. Herty in 1911. In the early experiments, made to demonstrate the advantages of replacing the box system by the cup system, the boxes were cut in winter and cornered in late winter. The first streak was made somewhat later along the upper edge of the wound made by cornering. In the case of the cupped trees, on the other hand, no such severe wound was inflicted. The trees, however, were cornered—that is, the bark and some of the wood were removed in order to obtain a suitable surface for the gutters. The first streak was cut at a little distance above the curved rim of the cornered surface. The ends or corners of the streak were farther above the cut surface than the peak and consequently did not reach directly to this open wound made some time before. Until May the yield of gum was notably less in the cupped trees than in the boxed trees, which had received a more intense wound stimulus.

Wounding the outer sapwood, therefore, in this manner (or even less severely, as is the practice on the Florida National Forest and in India) appears to have a very definite effect on the early yield of gum. It was estimated by one operator, for instance, that this practice gained for him, on one operation, a total of \$500,000 in one year.¹⁶ This practice, strongly advocated by Dr. Herty, was repeatedly employed with success. The theoretical explanation of it, advanced by him on the basis of the results of Tschirch's¹⁷ investigations on other resin-yielding trees, was however not in accord with the facts. His deduction was as follows:

Immediately after cornering (late winter) the formation of secondary resin ducts begins at all points of the cut. Later when the tree is chipped, these secondary ducts are opened along the full length of the cut and a good yield is consequently at once obtained.¹⁸

¹⁵ For. Serv. Bul. 90, p. 28.

¹⁶ Herty, C. H., "The Turpentine Industry in the Southern States." Jour. Franklin Institute, March, 1916, p. 362.

¹⁷ See footnote p. 3.

¹⁸ For. Serv. Bul. 90, p. 28.

As has been shown, no induced resin passages were present and no wood formation occurred until the latter part of April. Consequently this increased early yield came from the induced responses of the resin passages already present in the round timber. These apparently were stimulated to greater activity by the advance streak than would have been produced by ordinary chipping later in the season.¹⁹

Observant operators were often aware of the fact that men who started operations with a little chipping very early in the season generally obtained high yields. The following statement by a practical man, whose family has been in the turpentine business for four generations, bears directly upon this point:

It has been a matter of common experience with everyone familiar with turpentine that with a box cut late in the season, followed by chipping immediately thereafter, the yield of gum is very little for the first two or three months of the season. * * * If you chip any face at one time 3 inches up, the face will not run well for two or three months following.²⁰

Apparently the region just above the wound is profoundly influenced by it, but the response may not be apparent at once. This idea is incorporated in the standard Forest Service practice on the Florida National Forest, where it is the custom to cut one streak when the aprons (metal strips used instead of gutters) are placed; that is, the streak is cut some weeks in advance of the regular chipping. (See Pl. I, fig. 3.)

The influence of the advance streak is not only a factor in the case of the response of the ordinary resin passages, formed in the round timber, but is also probably manifested in the amount and responses of the resiniferous tissue found in the new wood which is formed as the season progresses. Similar responses may underlie the following observation, namely, that in the second year of the turpentine operation resiniferous tissue occurred somewhat earlier in the new growth ring than it had in the first year of the operation. Some experiments on obtaining the gum storax from red gum trees also appear to show a somewhat analogous situation.²¹ These trees, which normally have no resin passages, develop them as a result of wounding. In the case of red gum trees which were wounded as late in the spring as May 30, the first response in the developing annual ring was the formation of normal wood. It was from four to six weeks later that the formation of functioning resin passages, as indicated by the presence of any considerable amount of gum exudation,

¹⁹ Since this was written it has been learned that the advance streak is recognized as essential in turpentine practice in India.

²⁰ Courtesy of Mr. A. Sessoms, of Bonifay, Fla.

²¹ Gerry, E., "American Storax Production," Jour. For. 19: January, 1921.

occurred. Here, as in the case of the pines, and even in that of the conifers studied by Tschirch in midsummer condition, considerable time was required to obtain the major response induced by the wound.

PART PLAYED BY RESIN PASSAGES FORMED AFTER WOUNDING.

When the new wood formation begins after wounding, one of the most striking features of the developing ring is the early differentiation of more resin passages than are normally found. As soon as these resin passages, induced by wounding, are formed, they add materially to the flow of oleoresin, since they are generally very numerous (Pl. II, fig. 3) and are often arranged in rather continuous tangential series (Pl. II, figs. 3 and 5). Although a considerable amount of gum comes from this newly formed resiniferous tissue, it seems doubtful if, as has been stated, it constitutes "the chief source of commercial crude turpentine."²² The term "secondary resin passages" has been used to describe the resiniferous tissue formed in the annual rings after turpentineing. In contrast to this the term "primary resin passages" has been applied to the resin passages present in the round timber. Both these terms seem undesirable, inasmuch as the distinction between the resin passages of the two regions is not clearly defined, and since a certain number of the so-called primary passages would have been present under any circumstances in the new wood. Which these are, it would be impossible to determine. The types of resin passages found will be discussed with reference to length and number in the following pages.

RESULTS OBTAINED BY DIFFERENT METHODS.

EXPERIMENTS AT COLUMBIA, MISS.

STANDARD PRACTICE.

The operating methods termed "standard" in this report are the regular methods practiced by the company with which the cooperative experiment here described was carried on. The chipping was somewhat heavier than that known as the standard Forest Service method. In the Standard chipping as practiced at Columbia, Miss., the streaks were cut with a No. 2 hack or chipping tool. (See Pl. IV, fig. 2.) The weekly streak varied in depth from one-half to three-fourths inch and was about one-half inch in height. The type of forest, as indicated in Plate I, figure 2, consisted of large mature timber, but included also many old but relatively small suppressed trees. The chipping began early in the spring of 1916. The first material for microscopic study was collected in April, after four or five streaks had already been cut. The yield from

²² For. Serv. Bul. 90, p. 27.

about 5,300 cups, operated by this method, was separately recorded, so that it could be compared with the yield obtained from the trees on similar stands of timber adjacent, which were operated by the two special methods under experiment.

This operation was carried on for a period of two years. Figures 1 and 2 give the monthly observations on the five trees selected in 1916 and in 1917 (not the same five trees both years). The number of tracheids counted in a radial direction across the ring indicates the diameter increase since the beginning of the year. The fluctua-

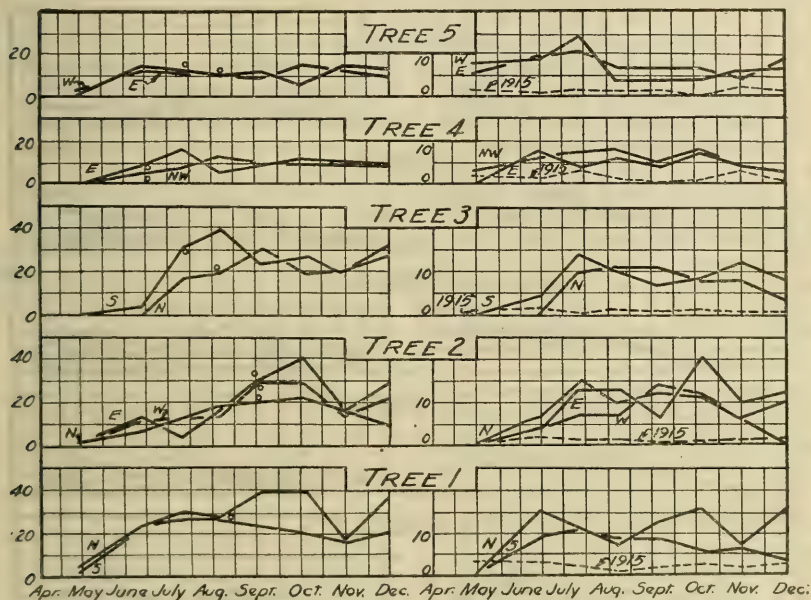


FIG. 1.—Standard trees, 1916.

Number of tracheids, observed April to December; in 1916, growth ring. °Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed April to December, 1916; in 1915, growing ring; in 1915, completed ring.

tions in the number of resin passages present are also shown. In Tables 2 and 3 are given the relative increases and decreases in width of annual ring and percentage of summer wood as observed in December, 1916, in 50 trees chipped by each of the three methods under observation and in 20 unturpented trees. In Table 4 are given similar observations for the years 1915, 1916, and 1917.

In 1916 considerable variation was found in the number of tracheids observed from month to month in the specimens from the five selected trees. (Fig. 1.) The width of the 1916 annual ring in the specimens cut near the end of the season was in several cases

less than that observed at lower levels earlier in the year. The number of resin passages per unit area²³ also was often smaller at the end of the season, but was throughout larger than that in the round timber. In 1916 this material was taken wherever a good chip chanced to be cut along the streak.

In 1917 care was taken to cut the specimens midway between the peak and the corner in all cases. By comparing figures 1 and 2, it is apparent that marked variations occurred, nevertheless, in the

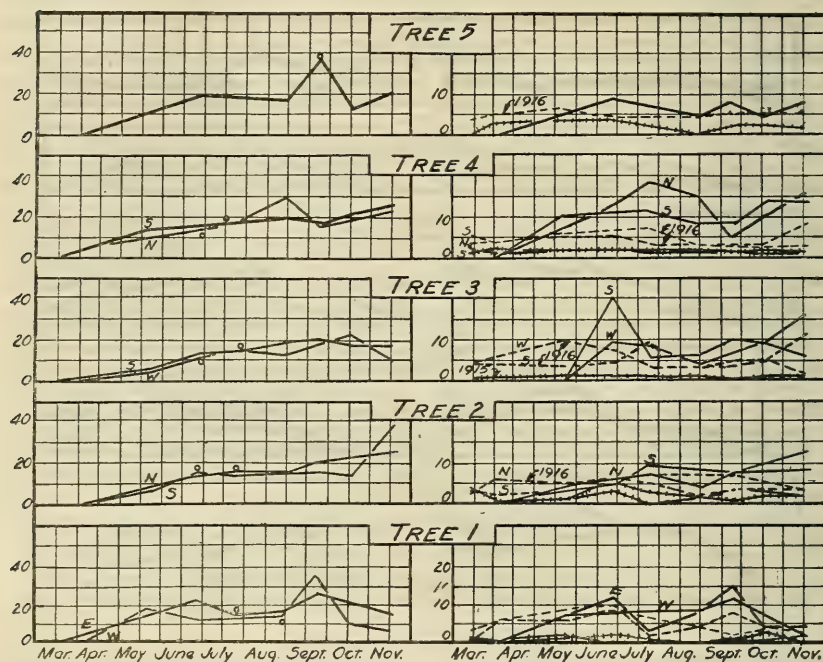


FIG. 2.—Standard trees, 1917.

Number of tracheids, observed March to November; in 1917, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed March to November, 1917; in 1915, 1916, and 1917, growth rings.

1917 material. Consequently these variations may be considered as characteristic of the annual ring, whether studied in the same or in different parts of its circumference and at different heights in the tree. During 1917, furthermore, many more resin passages than were normally found were produced, but at the levels where

²³An arbitrary unit made up of the portion of the annual ring in question which could be included in a microscopic field of a given magnification, the diameter of which was moved so as to include the approximate rectangle bounded by the beginning and end of the annual ring.

the 1917 material was cut it was obvious (fig. 2) that the number of resin passages present by June or July in the 1917 ring was greater than in the 1916 ring; and at no time in 1917 was the maximum number of resin passages in the 1916 ring as great as the maximum number in the 1917 ring. If, on the other hand, the number of resin passages present in the July, 1916, material cut in 1916 (fig. 1), is compared with the 1917 material cut in 1917, it is apparent that approximately similar numbers of resin passages were present.

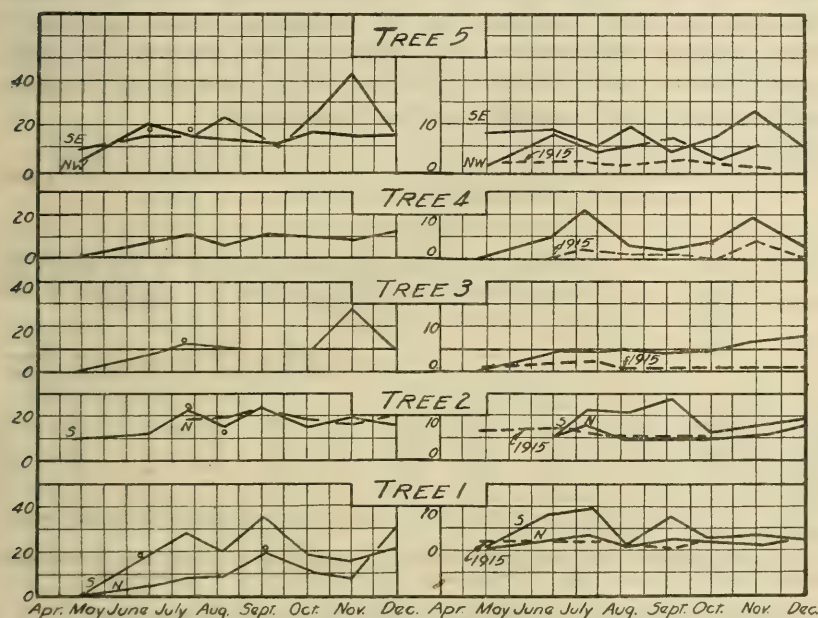


FIG. 3.—Double trees, 1916.

Number of tracheids, observed April to December; in 1916, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed April to December, 1916; in 1916, growing ring; in 1915, completed ring.

The conclusion therefore seems justified from this and other data that some of the resin passages are shorter than others, and are entirely cut away as chipping progresses. The microscopic observations indicate that in the case of the standard tract, the trees, judged by their wood formation in the neighborhood of the faces, a region where the wound response is very pronounced, did not suffer seriously from the effects of turpentine by this method for a two-year period. The wood formation was reduced more than in the case of the narrow chipping, as is brought out in the comparisons given in Tables 2 to 4. From Table 2, for instance, it is apparent that in

1916 many trees, 36 to 78 per cent, according to the position from which the material was taken, showed no decrease in ring width following turpentineing. Also (see Table 3) 26 to 64 per cent showed no decrease in the amount of summer wood formed, and the summer wood appears to be one of the most readily affected structural features. In Table 4, covering both 1916 and 1917, similar results were shown; but the decreases in 1917, the second year of the operation, are somewhat larger in the case of this type of chipping than they were in 1916. The size of the resin passages also decreased somewhat as time went on. On the average a greater number of resin passages per unit area was formed on this tract in 1917 than on the double tract. In both 1916 and 1917, however, the number on the narrow tract exceeded that on the standard.

TABLE 2.—Comparison of the annual rings formed in round timber (1915) and turpentineed timber (1916).

Number and kind of specimens.	Trees showing increase in ring width, 1916 (percentage of total number).			Trees showing no decrease in ring width, 1916 (percentage of total number).			Trees showing decrease in ring width, 1916 (percentage of total number).		
	Chips.	Increments.	Average.	Chips.	Increments.	Average.	Chips.	Increments.	Average.
20 trees untapped.....		70	70		95	95		5	5
50 trees narrow ¹	64	60	62	64	82	73	36	18	27
50 trees standard.....	26	56	41	36	78	57	64	22	43
50 trees double.....	44	50	47	58	76	67	42	24	33

¹ The narrow specimens showed more resin centers in the *chips* than were apparent in the standard and double specimens.

NOTE.—The *increment borings* were made on the tree at a distance of 2 to 3 inches from the face and at the same height as the last streak. The *chips* were obtained at the cutting of the last streak.

TABLE 3.—Comparison of the amounts of summer wood formed in the round timber (1915) and the turpentineed timber (1916).

Number and kind of specimens.	Trees showing increase in amount of summer wood, 1916 (percentage of total number).			Trees showing no decrease in amount of summer wood, 1916 (percentage of total number).			Trees showing decrease in amount of summer wood, 1916 (percentage of total number).		
	Chips.	Increments.	Average.	Chips.	Increments.	Average.	Chips.	Increments.	Average.
20 trees, untapped.....		70	70		75	75		25	25
50 trees, narrow ¹	54	44	49	60	70	65	40	30	35
50 trees, standard.....	20	50	35	26	64	45	74	36	55
50 trees, double.....	26	28	27	38	44	41	62	56	59

¹ The narrow specimens showed more resin centers in the *chips* than were apparent in the standard and double specimens.

NOTE.—The *increment borings* were made on the tree at a distance of 2 to 3 inches from the face and at the same height as the last streak. The *chips* were obtained at the cutting of the last streak.

TABLE 4.—*Comparison of ring width, summer wood, and resin passage formation for 1915, 1916, and 1917.*

Operation.	Number of trees examined for—		Amount of wood formed.				Average resin centers per one-eighth inch cross section (Nov. 17, 1917). ¹					
			1916 compared to 1915.		1917 compared to 1915.		1915		1916		1917	
	1916	1917	Total ring. ²	Summer wood. ²	Total ring. ²	Summer wood. ²	No.	Size.	No.	Size.	No.	Size.
Standard chip-ping.	102	52	<i>Per ct.</i> -34.0	<i>Per ct.</i> -51.5	<i>Per ct.</i> -56	<i>Per ct.</i> -67	1.5	Medium	4.4	Largest.	8.3	Smallest.
Double chip-ping.	108	55	+66.0	+48.5	+41	+33	1.2	...do....	3.8	...do....	6.4	Do.
Narrow chip-ping.	101	51	-43.0	-63.0	-58	-56	.8	Smallest	4.7	...do....	9.3	Medium.
			+57.0	+37.0	+42	+44						
			-35.5	-41.5	-45	-45						
			+64.5	+58.5	+55	+55						

¹ In 1916 material it was noted that the narrow had more resin centers than the standard or double.² Minus sign (-) indicates decrease in width; plus sign (+) indicates same width or increase in width.TABLE 5.—*Comparison of yield data for 1916 and 1917.¹*

Plot.	Year.	Corrected number of faces or cups.	Total dip distilled.	Total rosin.	Total turpentine.	Calculated yield per crop (10,000 cups).	
						Rosin.	Turpentine.
Standard.....	1916	5,405	<i>Pounds.</i> 63,926	<i>Pounds.</i> 64,822	<i>Gallons.</i> 2,002.5	<i>Pounds.</i> 119,929	<i>Gallons.</i> 3,704
	1917	5,335	70,275	54,595	1,625.0	102,334	3,046
Narrow.....	1916	6,105	61,062	59,874	1,853.0	98,073	3,035
	1917	5,977	77,776	58,680	1,761.0	98,176	2,946
Double.....	1916	3,062	42,687	43,766	1,301.0	142,932	4,248
	1917	3,020	50,805	36,670	1,091.0	121,424	3,613

Plot.	Year.	Comparison of yields on the percentage basis.							
		Standard for respective years rated as 100 per cent for the given year. ²				1916 yield for each crop rated 100 per cent for that crop. ²			
		Rosin.		Turpentine.		Rosin.		Turpentine.	
		<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>	<i>Gallons.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>	<i>Gallons.</i>
Standard.....	1916	100	.....	100	.....	100	.....	100	.....
	1917	100	.....	100	.....	85.4	-14.6	82.2	-17.8
Narrow.....	1916	81.7	-18.3	81.9	-18.1	100	.....	100	.....
	1917	95.9	-4.1	96.7	-3.3	100.1	+ .1	97.1	-2.9
Double.....	1916	119.1	+19.1	114.6	+14.6	100	.....	100	.....
	1917	118.6	+18.6	118.7	+18.7	85.0	-15.0	85.2	-14.8

¹ Compiled from monthly field reports for 1916 and 1917.² Minus (-) indicates loss; plus (+) indicates gain.

TABLE 6.—*Comparative yields per crop (10,000 cups) with respect to height of face (inches), 1916 and 1917.*¹

Plot.	Year.	Height of face.	Number of streaks.	Average height of streak.	Turpentine.			
					Total yield per crop.	Yield per inch of face height.	Increase in percentage (standard rated 100 per cent).	Comparison of percentage (year 1916 rated 100 per cent). ²
		<i>Inches.</i>		<i>Inches.</i>	<i>Gallons.</i>	<i>Gallons.</i>		
Standard.....	1916	21.95	38	0.58	3,704	169	-----	100.00
	1917	20.00	39	.51	3,046	152	-----	90.00
Narrow ³	1916	³ 12.85	38	³ .34	3,035	236	39.6	100.00
	1917	13.00	38	.34	2,946	227	49.4	96.2
Double ³	1916	³ 23.67	70	³ .34	4,248	179	5.8	100.00
	1917	19.00	72	.26	3,613	190	25.0	106.2

Plot.	Year.	Rosin.			
		Total yield per crop.	Yield per inch of face height.	Increase in percentage (standard rated 100 per cent).	Comparison of percentages (year 1916 rated 100 per cent). ³
		<i>Pounds.</i>	<i>Pounds.</i>		
Standard.....	1916	119,929	5,463	-----	100
	1917	102,334	5,117	-----	93.5
Narrow ³	1916	98,073	7,632	39.7	100
	1917	98,176	7,552	47.6	98.9
Double ³	1916	142,932	6,039	10.5	100
	1917	121,424	6,391	25.0	105.9

¹ Compiled from monthly field reports for 1916 and 1917.² Minus (—) indicates loss; plus (+) indicates gain.³ The narrow and double areas had four standard streaks before the experiment started. The height of the four streaks averaged 2.75 inches (average from 25 measurements). With this allowance, the streaks on the narrow and double areas averaged 0.30 and 0.32 inch, respectively. The corrected height for the double faces is 22.20 inches and for the narrow faces 11.38 inches, which, in this latter case especially, would further improve its rating.

The comparative yields obtained are given in Tables 5 and 6. It is apparent that the total yield from the 1916 chipping was highest in the case of the double tract and lowest in that of the narrow. If, however, the narrow is compared to the standard with reference to height of face chipped, it is apparent that the narrow shows a gain of almost 40 per cent in the first year of the operation. During 1917, the second year of chipping, the results were even more strongly emphasized. The double showed about the same increase in total yield over the standard, but the narrow made a better relative showing than the year before, and nearly equaled the standard in total yield. With reference to the height of face, i. e., amount of chipping surface used to obtain the yield, the narrow showed almost a 50 per cent gain over the standard in yield per inch of height of face chipped.

In the second year in all crops there was some decrease in total yield. The 1917 comparisons, using the total 1916 yields from a crop as 100 per cent or the criterion for judging the relative yield of that crop, showed that the greatest decrease occurred in the standard tract.- (Table 5.)

DOUBLE CHIPPING.

The special feature of this method, used for two years on this area at Columbia, Miss., was that the streak was cut at four-day intervals instead of only once each seven days. This type of chipping was used (Pl. IV, figs. 3, 5, and 6) on about 3,000 faces on the same kind of timber as that in the standard experiment. Only as much wood as was cut in the standard chipping was removed by this double method, since the dimensions of the streak specified were one-half inch deep and one-fourth inch high, cut twice weekly. The depth in general tended to average slightly less in the double than in the standard. During 1916 the chipping was carried on with a "00" hack (Pl. IV, fig. 2) and a streak averaging 0.32 inch was obtained (Table 6, footnote). In 1917 a "puller" (Pl. IV, fig. 6) was used, and a more accurate narrow chipping or rather "pulling" was obtained (average 0.26 inch) as is indicated in Table 6. This was also more accurate chipping than was obtained in 1917 on the single narrow-chipped area (average height of streak 0.34 inch), where a hack was used. It is of considerable interest to note that with this narrow chipping the double showed a smaller relative reduction in the second-year yield of turpentine, when compared to that of its first-year yield, than was shown by the wider-chipped (one-half inch per streak) standard. This was true in spite of the fact that the vitality of the double-chipped timber had apparently suffered rather more severely from the process of turpentineing than had the standard.

In figures 3 and 4 are given the monthly observations on the five trees selected from the double area for 1916 and 1917, respectively (different sets of five each year). The same reduction as in the case of the standard was noted in the number of resin passages per unit area of the 1916 ring, as was observed in material cut at the level of the 1917 chipping. The tendency for fewer resin passages to be present at the end of the 1917 season than in midsummer was also observed. In 1917 practically all five trees from the double area showed that their wood formation had suffered as a consequence of that method of turpentineing, and that they had not been able to recover, as many of the narrow-area trees had, or even been able to hold their own during 1917, the second year of turpentineing, as some of the standard-area trees appeared to have done.

The results from the examinations of the 50 specimens collected at the end of the season each year are given in Tables 2, 3, and 4. In

Tables 2 and 3 results are given from a set of chips obtained at the last streak cut and a set of increment borings made 2 to 3 inches to the side of the face at the height of the last streak. The borings, in general, showed less effect from the turpentine than the chips, indicating that the response to the wound was not as marked tangentially or circumferentially as it was vertically. The double and the standard both showed more reduction in wood formation than the narrow, as indicated by ring width. Judged by the borings alone, the double showed slightly greater reduction than the standard. The chips, on the other hand, showed more reduction in ring width in the standard than in the double. This tendency, however, did not hold for the

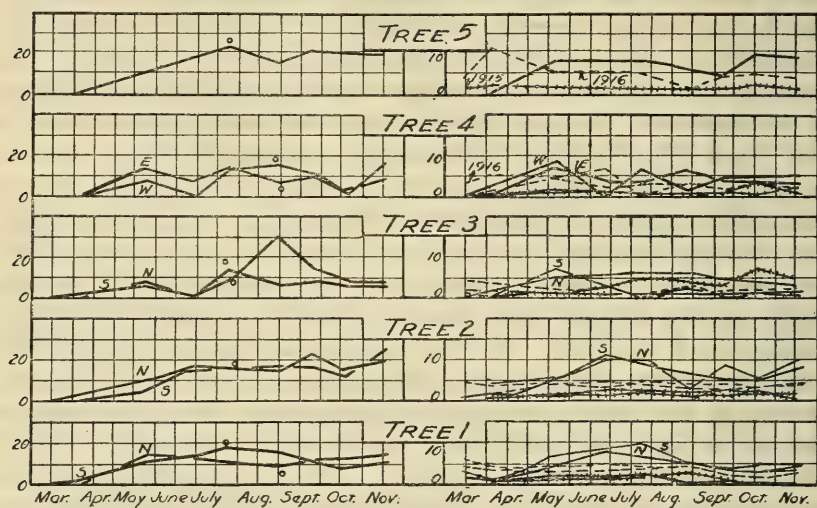


FIG. 4.—Double trees, 1917.

Number of tracheids, observed March to November; in 1917, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed March to November, 1917; in 1915, 1916, and 1917, growth rings.

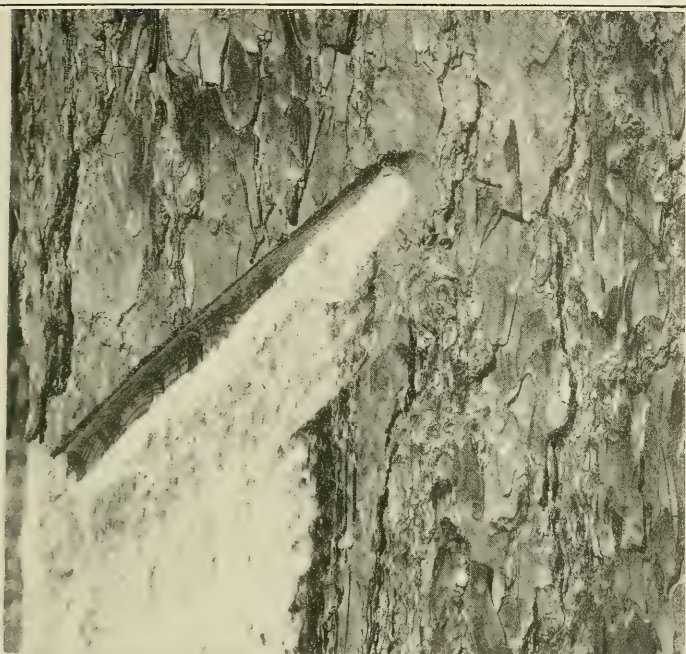
amount of summer wood present, which was exceptionally reduced in the specimens from the double tract. It would appear that the double chipping produced a special response which was manifest in the increased ring width shown by the chip specimens and in the sustained relatively high yield for the second year, which has been mentioned. It would seem, however, that this response was accomplished at the expense of summerwood production and of the tree's vitality in general, judging by such indications as these and by the frequent occurrence of "dry" faces in this crop. The double also produced fewer resin passages than the narrow. In 1917 (Table 4) the reduction in wood formation in the specimens collected from 50

PLATE III

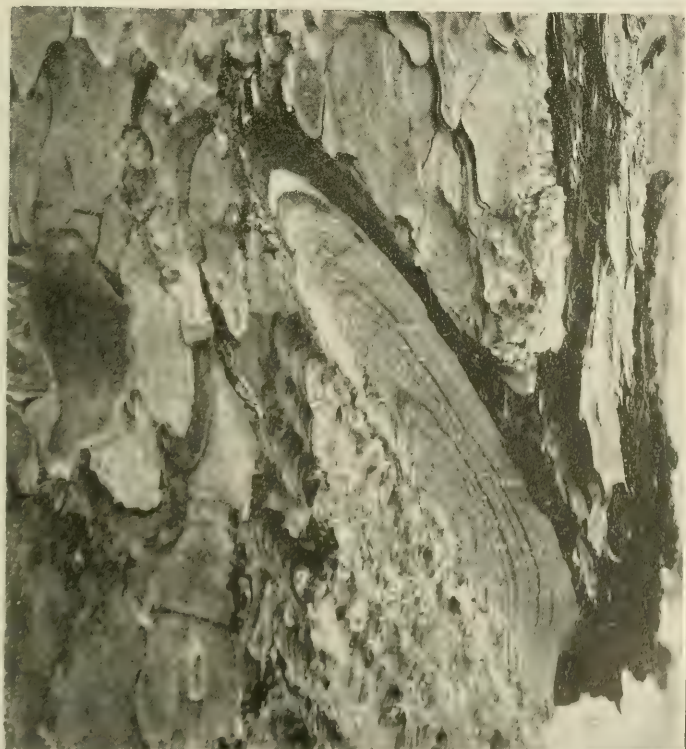
FIG. 1.—A face from the double-chipped area, Columbia, Miss., in November, 1917, at the end of a 2-year operation. Tree freshly chipped, dry-facing beginning at peak, gum exuding well at shoulder or corner. Droplets indicate the position of resin passages.

FIG. 2.—A face from the narrow-chipped area, Columbia, Miss., in November, 1917, at the end of a 2-year operation. Tree freshly chipped. Abundant exudation all along the streak. Each droplet at a resin passage, clusters and lines of droplets indicate series of resin passages. Fourteen or more annual rings of sapwood exposed and participating in the yield.

1



2



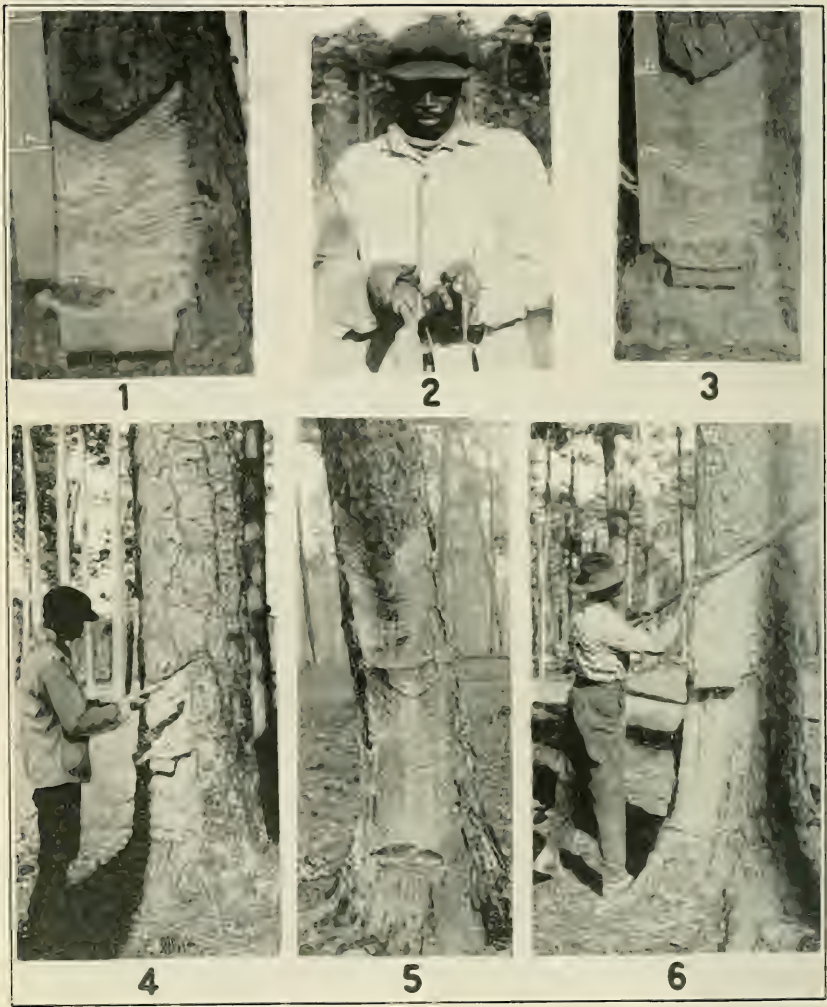


PLATE IV

- FIG. 1.—Face from narrow-chipped area at the end of the first year of turpentining (1916). About one foot in height of chipping surface used.
- FIG. 2.—The hack to the left of the picture is a "00." This type was used in the narrow and double chipping at Columbia, Miss. The broad "billed" hack to the right is a "No. 2," the type used in the standard chipping at Columbia, Miss.
- FIG. 3.—Face from the double-chipped area at the end of the first year of turpentining (1916). About two feet in height or twice as much chipping surface was used here as in the case of the narrow chipping. (Compare figure 1.)
- FIG. 4.—Low face on narrow chipping at end of second year of turpentining (November, 1917). Note paddle over cup to keep out trash.
- FIG. 5.—A dry face. A considerable number of trees on the double-chipped tract at Columbia, Miss., showed dry faces during the second year of the operation, indicating reduced vitality of trees.
- FIG. 6.—Relatively high face on the double-chipped area at the end of the second year of turpentining (same height as standard chipping). Note chip-catcher attached to puller. Somewhat higher yields may be obtained by this method in short operations.

trees from the double area at the end of the season was more pronounced than that of the year before.

The yields from the double area presented in Tables 5 and 6 show that a higher total quantity of gum was obtained by this method than by either the standard or the narrow chipping. From Table 6 it is also apparent that under the careful narrow "pulling" practiced in 1917 there was a marked gain over 1916 in yield, with reference to amount of face used. A slightly higher relative proportion of turpentine, as compared with rosin, was obtained by this method in both 1916 and 1917. It is questionable, however, whether the extra yield obtained is sufficient to justify the cost of the extra chipping, especially since the microscopic investigations showed that the responses of the trees on the double area, as expressed in the reduction of wood formation (Tables 2 and 3) and in the somewhat more belated and less abundant formation of resiniferous tissue, particularly in the spring of 1916, were less satisfactory than the responses obtained with the other methods of turpentineing. Yet if a case occurs in which timber can be turpentineed only for a short period (one or two years) before it is cut, this method might deserve consideration, especially if practiced only during the height of the producing season.

NARROW CHIPPING.

Narrow chipping was practiced on about 6,000 faces at Columbia, Miss., for a period of two years. The results obtained gave information worthy of careful consideration and further test, since they indicated a means of securing a high sustained yield for a considerable number of years with a comparatively small reduction in the vitality of the trees turpentineed. The streak specified was of the same dimensions (one-half inch deep and one-fourth inch high) as that used on the double area, but it was cut only once each week. The type of forest was the same as that turpentineed by the standard and double methods. Figures 5 and 6 show the results obtained from the monthly observations on the five trees selected for 1916 and 1917, respectively. Tables 2, 3, and 4 show the results of observations on larger numbers of specimens obtained at the end of the season each year.

Yields from narrow chipping.—The summarized yield data for 1916 and for 1917 are given in Tables 5 and 6. During the second year of operation the narrow crop produced within 4 per cent of the total yield of the standard crop, although during 1916, the first year of the operation, it had fallen 18 per cent below. With the narrow method, however, the usual second year reduction in yield was practically eliminated; whereas about 15 per cent reduction occurred in the standard and double when the yield of the second year was compared with that of the first.

With respect to per cent of yield as compared to amount of chipping surface used up, the narrow method was markedly superior to the other two methods. In 1916 it showed an increase in yield per inch of height of face of about 40 per cent, and in 1917 of nearly 50 per cent, over the standard.

The productivity of the trees on the narrow area at the end of the second year of operation, even after a long period of dry weather, was very high as compared with that of the trees on the double area. Photographs of freshly cut streaks made immediately after chip-

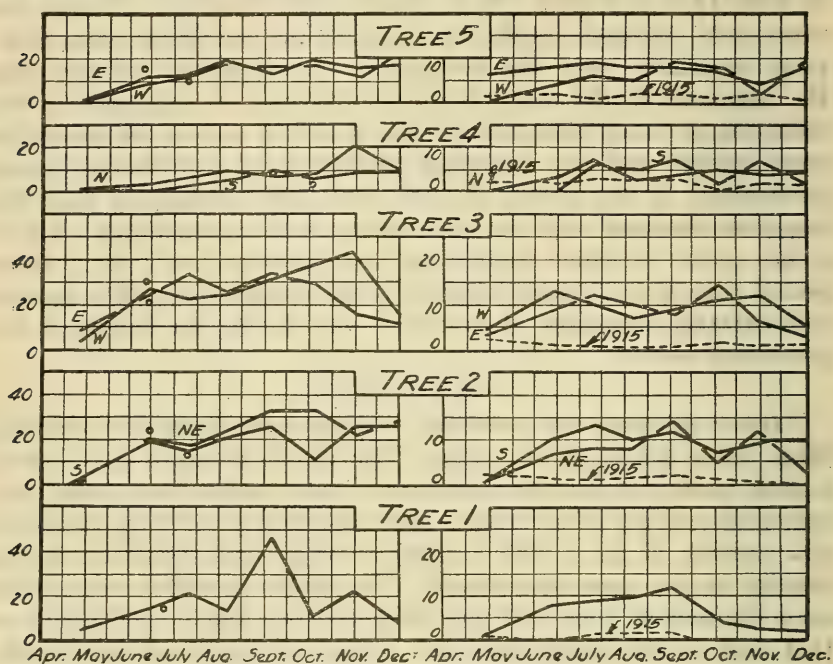


FIG. 5.—Narrow trees, 1916.

Number of tracheids, observed April to December; in 1916, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed April to December, 1916; in 1916, growing ring; in 1915, completed ring.

ping are shown in Plate III, figures 1 and 2. The abundant exudation of the gum from the narrow-chipped tree shown, even under adverse weather conditions, was so striking that the practical turpentine operator who was managing many crops in that section, and had been very skeptical of the narrow method of chipping, expressed surprise and satisfaction at the excellent condition of the timber. Not all the double-crop trees had "dry-faced" to the extent shown in Plate III, figure 1, but many were in that condition, and the yielding capacity was in general markedly reduced.

Production of resiniferous tissue.—Many more resin passages than are normally present were formed in the wood which developed after wounding. (Figs. 5 and 6.)

In both the 1916 and 1917 rings the greatest number of resin passages per unit area was present in the specimens from the narrow-chipped trees, although the average number present in the 1915 ring, when the timber had not been turpentine, chanced to be smaller (Table 4) than in the case of either the standard or the double specimens. In 1916 the earliest formation of resin passages was also found in the narrow-tract specimens.

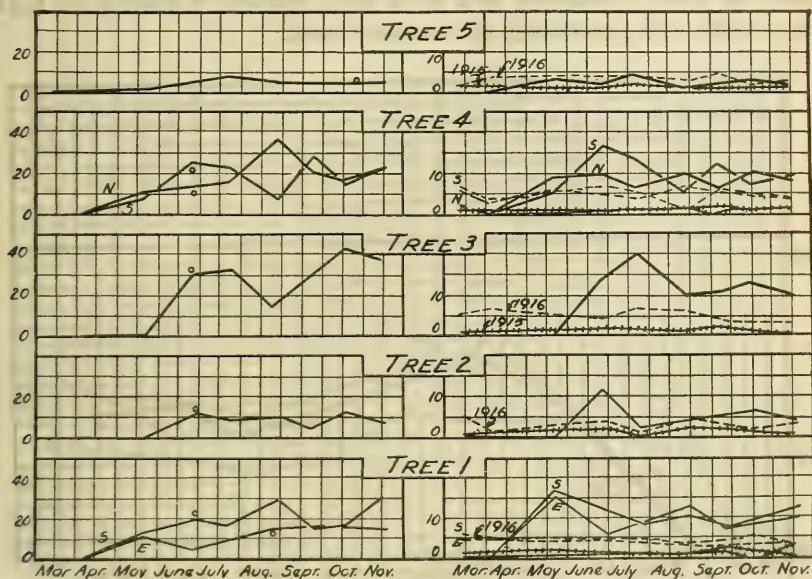


FIG. 6.—Narrow trees, 1917.

Number of tracheids, observed March to November; in 1917, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed March to November, 1917; in 1915, 1916, and 1917, growth rings. —, 1915; —, 1916; —, 1917.

At the level of the 1917 chipping, fewer resin passages per unit area were present in the 1916 rings than at the lower levels, judging the latter from the specimens studied during their development in the 1916 growing season. This was also true in the other two methods practiced. Some, but not all, of the resin passages induced by wounding were therefore apparently relatively short and appear to have been cut away as chipping progressed up the tree.

The largest resin passages found in the narrow material collected in 1917 were present in the 1916 ring, which was produced during the first year of turpentine. The year 1916 was found, further-

more, to be the best for wood formation, as was shown by the comparative observations made on material showing the 1915, 1916, and 1917 growth rings. The maximum number of resin passages per unit area found in 1917 was not present even at the end of the 1917 season (fig. 7).

Wood formation under narrow chipping.—The width of the annual ring, the time when wood formation begins, and the amount and density of the summer wood, appear to serve as very good criteria of the extent to which the tree is affected by turpentineing. A very severe chipping was generally found to be followed by a delay in wood formation and by a very marked reduction in both ring width and percentage of summer wood.

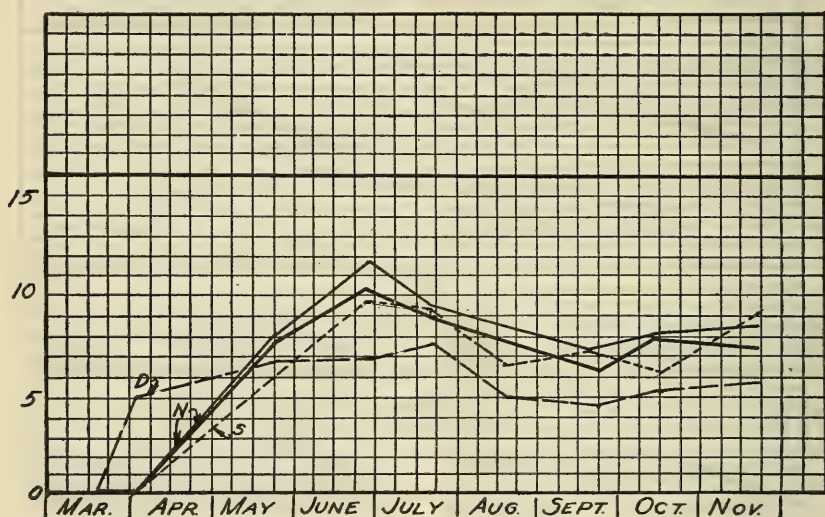


FIG. 7.—Number of resin centers, 1917, based on averages of five trees per crop, as observed monthly. S, standard; N, narrow (top light line is the average of four normal narrow trees with one dying tree left out); D, double.

The wood structure observed in the specimens from the narrow-chipped tract at Columbia, Miss., as shown in Tables 2, 3, and 4, approached most closely the wood formation of the round or unturpentineed timber from that section. The width and character of the summer wood were also much nearer normal than in the specimens cut from the standard and double tracts. Hence it might be said that wood formation in general suffered little, or sometimes not at all, from this method of turpentineing. In other words, the vitality of the timber and its capacity to respond were less reduced by narrow chipping than by either the standard or the double method. The narrow-chipped trees in many cases (Pl. V, figs. 3 and 4) showed more wood formation in 1917 than in 1916, in spite of the fact that 1917,

PLATE V

In each case the specimens came from the Columbia, Miss., tract and were cut midway between the shoulder and the peak at the streak. The bark is shown at the top of each figure. The two annual rings next the bark (top) were formed during turpentineing in 1916 and 1917, respectively. The other rings (below) were formed by the unturpentineed timber. In all figures the greatest number of resin passages is present in the rings formed after turpentineing.

SPECIMENS FROM THE DOUBLE-CHIPPED AREA CUT NOVEMBER, 1917

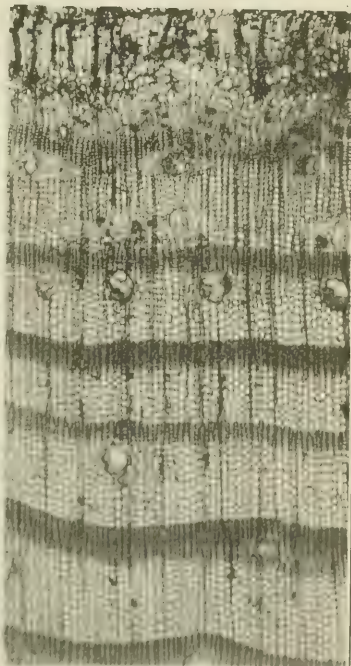
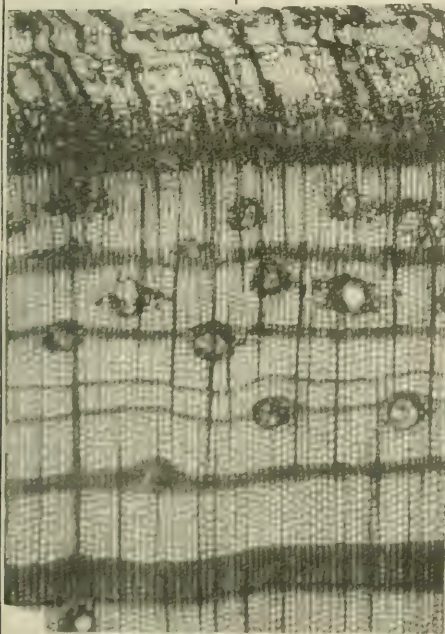
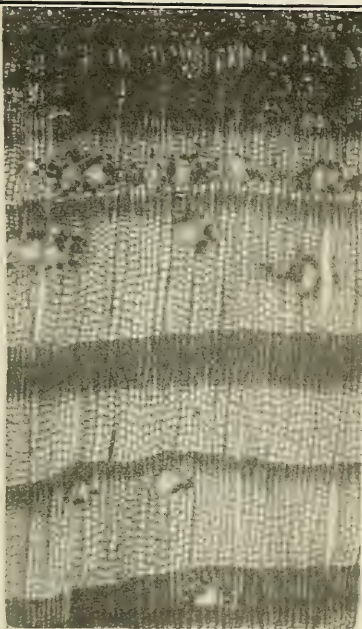
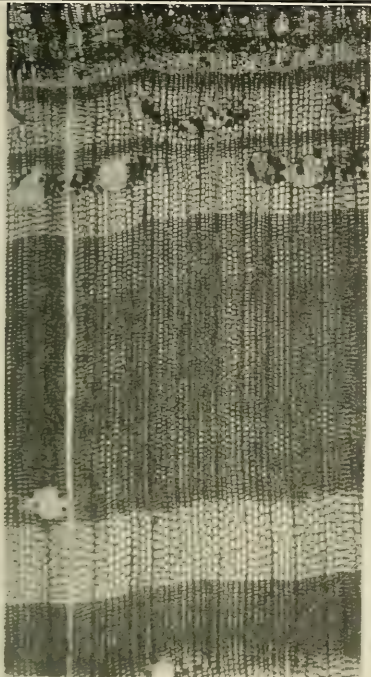
FIG. 1.—Marked reduction in ring width and amount of summer wood accompanying turpentineing. This was generally greatest in trees with vigorous wood formation.

FIG. 2.—Tendency to increased ring width in 1916 but reduced summer wood formation. Both ring width and summer wood were reduced in 1917. At this height resin passages are present earlier in the 1917 spring wood than in that of 1916, where probably short resin passages, formed in 1916, have been cut away by chipping.

SPECIMENS FROM THE NARROW-CHIPPED AREA

FIG. 3.—Specimen cut November, 1917. The 1916 and 1917 rings are both wider than the rings formed during the three years previous by the unturpentineed timber. The 1917 ring is somewhat wider than the 1916 ring, showing the sustained vitality of the tree in spite of turpentineing, and of a poorer season in 1917.

FIG. 4.—Specimen cut July 24, 1917. Here also sustained vigor associated with this rather conservative method is apparent. Note the closed condition of the resin passages.



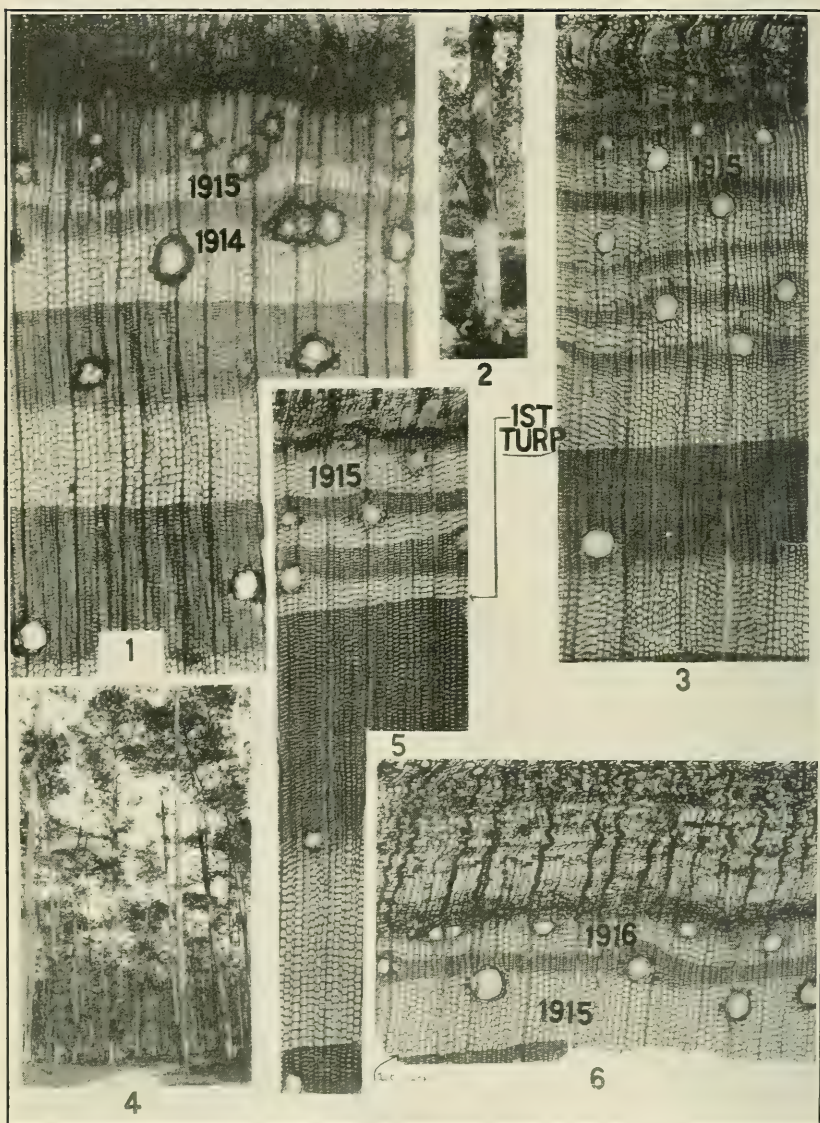


PLATE VI

FIG. 1.—Cross section, cut April 24, 1916, from the peak, about 6 feet above the ground, of one of the trees shown in figure 4. The effects of 2 years of heavy chipping are manifested, even in this vigorous timber, by reduction in width of ring and in amount and density of summer wood in the 1914 and 1915 rings. More resin passages than usual are present. The effect of the wound is apparent in the wood formed 6 feet above it in the 1914 ring. No wood formation for 1916 had occurred. Material from near Bogalusa, La.

FIG. 2.—A boxed tree heavily chipped for five years. Wood structure shown in figure 3. Tree near Florida National Forest.

FIG. 3.—Specimen cut from the peak of the tree shown in figure 2, about 8 feet above the ground. The response to turpentine is apparent in reduced wood formation in the five annual rings next the bark (top). The effects in the ring formed when turpentine was first begun were produced about 8 feet above the wound. The specimen was cut in May, 1916. No wood formation for that year was yet apparent.

FIG. 4.—Timber of which the specimen shown in figure 1 is an example.

FIG. 5.—Very heavy chipping was used on this small tree for 3 years. The wood formation was markedly reduced. The specimen was cut May 6, 1916. No wood formation for that year had occurred.

FIG. 6.—Specimen from a conservatively chipped small tree. (Second year of turpentine by the French method.) This tree is from the same locality as the specimens shown in figures 3 and 5. Here, however, 5 or 6 rows of wood cells and one series of resin passages were already formed by May 6, 1916 (top next bark). In 1915, the first year of turpentine, summer wood formation was not reduced in this specimen.

judging from the wood formed by the round timber, was not such a favorable growing year as 1916. Hence it would appear that the narrow method of chipping not only permitted a nearly normal wood production but also a very marked increase in resiniferous tissue.

It is greatly to be regretted that the same operation could not have been continued for at least two years longer, in order that still fuller results from this very promising method might have been secured. In this regard it is of interest to compare the results obtained from an earlier Forest Service experiment, and likewise those from the Florida National Forest, where the chipping is only slightly wider than that actually used on the narrow tract and where this method has been practiced successfully for a period as long as six years. Information clearly indicating the advantages of narrow chipping has also been gleaned here and there from conversations with observing and experienced practical turpentine operators. This evidence, in addition to the positive evidence presented as a result of the present study, definitely points to the importance of further practice of the method, to the end of obtaining conclusive results on a large scale and over a period of four or more years. It is especially desirable that data from narrow chipping on small young timber should be secured.

• STANDARD FOREST SERVICE METHOD OF TURPENTINING.

The method of turpentineing practiced on the Florida National Forest is designated as the "standard Forest Service method."²⁴ In the Forest Service leases issued to those who rent timber for the purpose of turpentineing, the following requirements were made, subject to inspection by forest officers during the operation of the permit. All unmarked living trees 10 inches and over in diameter, breast-high, were cupped with not more than one face on trees 10 inches to 15 inches in diameter; with not more than two faces on 16-inch to 24-inch trees; and with not more than three faces on any tree. It was customary to make the first streak of a virgin operation when the aprons were placed, some time before the regular chipping began. A No. 1 or smaller hack was required for chipping. Bark bars at least 4 inches wide were to be left between faces. The dimensions of the weekly streak specified were that it should be not more than one-half inch deep (not including the bark) and not more than one-half inch high. In practice the height cut never exceeded one-half inch, and on the areas observed sometimes tended to be slightly less. A total of not more than 16 inches in height

²⁴ Data obtained chiefly in 1916 and 1917 through the courtesy of Supervisor I. E. Eldredge and Deputy Supervisor E. R. McKee, and in 1921 from Supervisor L. L. Bishop, all of the Forest Service.

of chipping surface or working face (about 32 streaks) was allowed in any one chipping season, so that the operator was at liberty to use more streaks, provided they were less than one-half inch high. (Pl. VII, fig. 4.)

This method was found to give satisfactory and sustained returns even over periods of six or more years. Indeed, timber owners in the vicinity who observed the results thus secured voluntarily abandoned the heavier chipping which they had previously practiced in favor of this method. The question of whether the height of chip used could advantageously be reduced somewhat further—as the results of the narrow chipping at Columbia, Miss., indicated might be the case, at least on the timber of that section—is one needing immediate attention. The yield from the narrow chipping did not show appreciable reduction during the second year, as was generally the case with the crops operated by the standard Forest Service method.

EXPERIMENTS ON THE FLORIDA NATIONAL FOREST.

Very interesting results have been obtained by experiments made on the Florida National Forest near Camp Pinchot in an effort to find a system for working longleaf pine that would produce (at the same cost or, if possible, at smaller cost than that which now is customary in ordinary practice) as high an immediate yield of gum as is now obtained, and also a good sustained yield for a longer period. Some of the methods tested are illustrated in Plate I, figures 5 and 6. Special attention was given to finding a method adapted to application on relatively small, young, second-growth timber. A striking illustration of the effect of heavy as compared with conservative chipping on wood formation and general tree responses was observed when some material from the tract on which the French method of turpentining was being used was compared with specimens from very heavily chipped trees from the same locality on a private tract. Figures 5 and 6, Plate VI, illustrate the relative effects of these methods. Both specimens were cut on May 6, 1916. At that time practically no wood cells had been differentiated in the case of the heavily chipped tree (streak three-fourths inch or more deep and three-fourths to 1 inch in height), whereas a considerable number of wood cells and a number of resin passages had formed in the specimens from the French-chipped area. (Pl. VI, fig. 6.) Moreover, in this latter specimen the ring width and the amount and density of the summer wood formed after turpentining were not reduced, as compared with the conditions found in the round timber. In the case of the heavy chipping, however,

the marked reduction occurring during the three years of turpentine is very apparent, although some allowance must be made for the fact that the greatest reductions in ring width after turpentine generally occurred in the trees with very wide rings, hence at least a part of the reduction noted might be attributed to this characteristic.²⁵ In general, it may be said that wherever trustworthy evidence is obtained it points to the conclusion that conservative chipping which does not unduly reduce the vitality of the tree, leaving unturpented trees that are too small, not overcupping, and leaving sufficient bark bars pay in point of yields obtained and in reducing the number of trees which are killed or which dry-face.

EARLY FOREST SERVICE EXPERIMENTS.

Evidence pointing to the advantages of conservative chipping is also to be found in the results from some experiments carried on from 1905 to 1908.²⁶ The standard chipping of a commercial turpentine company not far from Jacksonville, Fla., was in this case used as a basis for comparison. It was slightly heavier chipping (streaks 0.6 to 0.7 inch deep and 0.51 inch high) than the standard chipping practiced in 1916 and 1917 at Columbia, Miss. Both slash and long-leaf pine were found in the stands of timber used. It was noted that the slash pine produced little or no scrape. The purpose of the work was to determine the results to be obtained from (1) shallower chipping, a reduction of depth of cut from 0.6 or 0.7 inch to 0.4 or 0.3 inch, the shallowest cuts being used on the slash pine; (2) narrower chipping, an intended reduction in height of one-half, which was, however, in practice a narrowing from 0.51 to 0.4 inch; and (3) light cupping, the cutting of fewer faces, and the elimination of turpentine of very small trees with a view to a second turpentine at some future time.

It was reported that considerable difficulty was found in obtaining exact and uniform chipping, because of the change of chippers from time to time on the different crops. Another possible source of some error in the results was the method of determining the relative yields from the different crops by weighing the dip and scrape instead of the turpentine and rosin distilled from it. This method was found to be misleading in the case of the results obtained at Columbia, Miss., where it was found that a high weight of crude gum might be partly due to water mixed with the gum during rainy periods, and that it did not always indicate a proportionally high yield of turpentine and rosin (Table 5).

²⁵A publication is in preparation by the Forest Service on the detailed results and relative yields from the different types of experimental chipping practiced on this tract.

²⁶ For. Serv. Bul. 90, p. 16.

TABLE 7.—*Early Forest Service experiments—Summary of total yields for 1905, 1906, 1907, and 1908 on the basis of the corrected amounts of dip and scrape (125 chippings).*

[Data from U. S. Department of Agriculture, Forest Service Bulletin 90.]

Crop.	Dip (oleoresin).		Scrape (hardened oleoresin).			Total number of chippings.	Average height of chippings.	Average depth of chippings.	Dead trees at end of second season.	Per cent of stand.	
	Yield.	Increase.	Yield.	Increase.	Decrease.					Long leaf.	Slash.
A. Standard chipping of Walkill Turpentine Co.	206,235	.....	47,742	.....	.....	125	<i>Inches.</i> 0.51 ¹	<i>Inches.</i> 0.7 to 0.6	121	57	43
B. Shallow chipping.	211,911	2.75	44,838	.....	6.08	123	.51 ²	0.4 to 0.3	73	48	52
C. Narrow chipping.	214,503	4.01	39,775	.....	16.69	124	.40 ²	0.7 to 0.6	64	46	54
D. Reduced number of faces, larger trees, prospect of back cupping ³	279,260	35.41	53,915	12.93	.....	119	.51 ²	0.7 to 0.6	58	51	49

¹ Minimum diameter of turpented trees 6 inches, 2 faces permitted on trees over 13 inches.

² Shallower cuts on slash.

³ Minimum diameter of turpented trees 10 inches, 2 faces permitted on trees over 16 inches. No more than 2 faces per tree.

A summary of the results obtained is given in Table 7. It is apparent that crop A (standard) showed a successive yearly decrease in yield and the greatest number of dry-faced and dead trees.

Crop B, the shallower chipping, showed in the four years of operation an increase in yield of about 3 per cent over the standard. This gain took place during the last two years of the operation. There was less relative yearly decrease in yields also than in crop A, and less scrape was formed, which fact, the writer pointed out, was in accord with the current idea that deep chipping produced much scrape. From these results it is concluded in Bulletin 90 that there is "no doubt as to the wisdom of shallow chipping."

In sharp contrast to this were the results from an operation visited in 1917 in Mississippi. The type of timber and the method of chipping employed are illustrated in Plate VII, figures 5, 6, and 8. The streak cut was about 0.75 to 1 inch in depth and a scant 0.5 inch in height, and a very high as well as a sustained yield was reported.²⁷ These trees were characterized by having very wide sapwood. Less than 1 per cent of the trees were lost through death from turpentinizing. Care and good judgment were exercised in the placing of the cups and in maintaining adequate bark bars between the faces on this timber.

It would appear from the foregoing that the question of the width of the sapwood and the responsive vigor of the timber on any given tract must be considered as of fundamental significance in determining the depth of the streak to be cut. That the resin passages in a

²⁷ Reported yield of 105 barrels of turpentine per yearling crop and an average of 82 barrels for different ages, including virgin and fourth-year workings.

considerable number of the outer sapwood rings are involved in the yields of gum obtained is evident from the discussion on pages 9 and 10 and from Plate III, figure 2.²⁸ It would therefore appear that the proportion of the sapwood which it is desirable to expose in chipping probably varies somewhat according to circumstances, and that the range of depth should be more exactly determined by further experiments on different types of longleaf and slash pine timber, especially on young timber, since this is of great future significance.

Crop C, the narrow chipping, did not have as narrow streaks as those cut at Columbia, Miss. Although it was intended that the streaks should be about one-fourth inch in height, it is stated that "in spite of continued urging and the closest supervision, the chippers invariably made the cut wider than was desired. * * * Nevertheless in spite of the failure to reduce the width of the cut as much as desired, a considerable decrease was made." The height of the faces at the end of 4 years on crop A (standard) was 64.3 inches, and on C, 50 inches, or an average height of chip of about 0.4 inch. Under the narrowed chipping this crop showed an increase over the standard which was greater than that secured by the shallow chipping of crop B. Furthermore, less dry-face and dead trees resulted, and about one year of chipping surface (14.3 inches) was gained. These facts, therefore, furnish another instance of successful narrow chipping. How far the streak can further be narrowed with advantage beyond this 0.40 inch and the 0.34 inch obtained at Columbia, Miss., and sometimes obtained in commercial "pulling," is a subject for further experiment.

Crop D, the light cupping at Walkill, Fla., where fewer faces were cut per tree and no tree under 10 inches was cupped, but where the standard streak was cut, gave the highest yield of all the crops and the least loss from dry-facing or death of trees. It should be borne in mind that on the other crops trees with a diameter as small as 6 inches were cupped, and two faces were permitted per tree on timber with a diameter of 13 inches and over. (See Table 7.) As has been recently shown, it is unprofitable from the point of view of the growth in length and diameter of the timber, as well as from that of the yield of gum, to turpentine too small trees by the methods generally practiced in the United States.²⁹ (See Table 8.)

It was demonstrated clearly both in the Walkill experiment and in Cary's observations (Table 8) that it was of fundamental importance to maintain the vitality and responsive power of the tree. Too large

²⁸ This fact was not recognized at the time that the conclusion in regard to shallow chipping was expressed in Forest Service Bulletin 90.

²⁹ Cary, Austin, "A look ahead" in *Naval Stores*, published by the Weekly Naval Stores Review, and in "Money is actually lost in working small trees for turpentine and rosin," *Naval Stores Review and Trade Journal*, Vol. XXX, Jan. 22, 1921, p. 14, and Nov. 19, Dec. 3, 10, 24, and 31, 1921, and Jan. 7 and 14, and Feb. 4, 1922.

and too numerous faces, which unduly reduce the relative percentage of uncut bark, are unquestionably harmful and unprofitable. The questions of depth and height of streak are intimately connected with the number of faces and the returns obtained, but further work is needed, as has been shown, to fix within narrower limits the range of the most successful depth and height of chipping. It is stated by careful operators that, at the very least, one-third of the bark should remain uncut, and undoubtedly a larger proportion is desirable. The area D at Walkill was so turpented that it would be possible to work it for a second period (back cup) some time later.

TABLE 8.—Yield at first dipping from trees of different diameters.

Diameter breast high (inches).	Set 1.			Set 2.
	Width of face (inches).	Yield (average of 15 trees).	In pe- centage of 10-inch trees.	Yield.
		Ounces.		Ounces.
5.....				4
6.....				6
7.....	7	10	44	8½
8.....	8	15	67	11
9.....	9	19	84	14
10.....	9½	22½	100	16½
11.....	10	23	102	19
12.....	10	24	107	21

¹⁴ trees.

TABLE 9.—Gain obtained by light cupping as compared with Standard chipping at Walkill, Fla.^a

Year.	Dip.		Increase.		Last three years compared to first.			
	A, stand- ard.	D, light- cupped.	Pounds.	Per cent.	A		D	
					Increase.	Decrease.	Increase.	Decrease.
	Pounds.	Pounds.						
1905.....	63,615	73,704	10,089	16				
1906.....	64,583	84,074	19,491	30	b 1½		b 14	
1907.....	43,675	69,286	25,611	58		31		6
1908.....	34,362	52,196	17,834	52		46		29

^a For. Serv. Bul. 90, p. 20.

^b This increase was chiefly due to the fact that in 1905 there were 31 streaks and in 1906, 35 streaks cut.

Because of the gains secured in the first three years of the Walkill experiments, a different experiment was instituted on two crops during the fourth year (1908), which combined both the shallow and the narrow chipping features. "Yearling" or second-year crops were used, and the yields of gum were compared with those from a similar adjacent crop chipped by the standard method. An increased production of about 35 to 38 per cent was secured in this experiment. The "dip" from these shallow and narrow-chipped

trees was also considerably richer in turpentine than the ordinary dip, and fewer dry faces and dead trees were found on these crops. In conclusion, therefore, it may be said that these early Forest Service experiments clearly showed the advantages of certain conservative turpentinizing methods, which as was at that time felt, were only an indication of what might be accomplished in this direction.

CHIPPING IN THE LIGHTWOOD.

There is a belief current among practical turpentine operators that, to obtain the best yields from turpentinizing a substantial amount of wood, a high chip should be cut away each week in order to "keep ahead of the lightwood." By lightwood is meant the region above the streak which is more or less saturated with oleoresin. The presence of lightwood is indicated by the difference in color between the surface of the freshly cut streak and that of a wound newly cut in round timber. It may be that the wood is only slightly impregnated with resin, so that the summer wood bands appear somewhat darker than normally, or, on the other hand, that a considerable amount of resin may have soaked into the wood, markedly darkening it, and often making the summer wood appear translucent, especially when the light is allowed to shine through a chip from such a region. An extreme example of this is shown in Plate III, figure 1, in which case the saturation probably occurred as a result of the undue drying out and dying of the overstimulated tree.

Narrow chipping, one-fourth inch to a strict one-half inch in height, will not keep ahead of all lightwood, especially during the midsummer season. For this reason many practical operators were convinced in advance that narrow chipping would fail. However, as has been shown, the results of reducing the height of the chipping speak for themselves in terms of increased yields and sustained vitality of the trees, as indicated, for instance, by the late autumn response shown in Plate III, figure 2, and by the recovery of the tree under turpentinizing, shown by the amount of wood formation in Plate V, figures 3 and 4.

The following interpretation of the observations made appears to be justified by the results obtained. When a tree is chipped or scarified the living cells in the wood are injured and a strong wound stimulus is given. Oleoresin exudes from the resiniferous parenchyma present. It tends to coat the surface and to cover it with a more or less complete seal, which materially assists in preventing the drying out of the exposed sapwood. Probably most of the parenchyma cells close to the surface of the wound, especially those actually cut, may die. The wound stimulus is undoubtedly greatest in the immediate vicinity of the wound. Its effect appears to be mani-

fested in the increased yields obtained by using the "advance streak." (See pp. 10 to 12.) The effect of the wound on the actively growing tissue is apparent in the tendency of the tree to heal or close the wound. More than the normal amount of parenchyma or resin-yielding tissue is formed, often at the expense of ordinary wood formation. More resin passages or resiniferous parenchyma aggregates were generally produced in a definitely limited region, 8 to 12 inches above the wound, than further above it, as is indicated by the resin passage graphs in figures 1 to 6. Twenty or more inches above the original wound the number of resin passages is notably reduced, as is shown by the 1916 data as compared with those of 1917 in figures 1 to 6. Nevertheless, the wound response giving evidence of the extent to which the stimulus is transmitted, although less marked at a distance, was manifested as far as 7 to 10 feet above the wound. (Pl. VI, figs. 1, 2, 3, and 4.) Both increase in resiniferous tissue, most marked in the transition wood and in the summer wood in the specimens from the higher portion of the tree, and often some reduction in ring width or summer wood formation, occurred in the wood produced after turpentineing. The chipping or freshening of the wound is designed to remove the dried and hardened surface of the streak and the unproductive parenchyma cells in order to permit the fresh exudation of the oleoresin, which forms and collects above this sealed surface during the period following the chipping. The chipping also serves to stimulate the living cells to further responses. It appears as if a very narrow chipping should successfully accomplish this purpose. It is obvious that a high chipping cuts away the most intensely stimulated and presumably the most responsive tissue, especially for gum production, in the tree. It is as if a whole organized battery of the tree's forces were wiped out at each stroke of the hack and a new organization had to be mustered afresh in the attempt to respond to the new condition. After a number of such responses, the results of which are cut away and wasted, the tree's resources tend to become more and more exhausted, and the yield of gum and the wood formation are reduced. Many trees under these circumstances become dry-faced—that is, physiologically speaking, their living cells cease production, and they frequently die (Pl. VII, fig. 3); at best the vitality of the timber is too severely taxed to assure the best returns possible.

In brief, then, chipping in the lightwood (progressing up the tree slowly less than one-half inch per week) is to be recommended because: (1) This is performed in the region of maximum stimulation, (2) it conserves chipping surface, (3) it tends to keep the surface from drying out because of the oleoresin saturating it to a greater or less extent, and (4) it has been found experimentally and practically to give sustained yields. Much "pulling" (see Pl. IV,

PLATE VII

- FIG. 1.—Well-placed faces. This insures the fullest return from the tree for the labor of operation.
- FIG. 2.—Bad placing of faces at the beginning of the operation. This means waste and loss at every stage.
- FIG. 3.—The effects at a later stage of placing faces too close together. Note dead and dry face.
- FIG. 4.—The beginning of the third year of turpentine, May, 1917, in a conservatively chipped tree. About 16 inches height of chipping surface was cut annually. Standard Practice Florida National Forest.
- FIG. 5.—The beginning of the sixth year of turpentine, June 6, 1917, on a well managed commercial operation. In its fifth year about 45 barrels of turpentine were said to have been made from this crop.
- FIG. 6.—One tree from the area shown in figure 8. This was the beginning (June 6, 1917) of the second year of this operation. Note chipping $\frac{3}{4}$ -inch to 1 inch deep. The sapwood in this case was about 3 inches wide. Thirty-three streaks were cut each year.
- FIG. 7.—Excellent opportunities for future turpentine are offered by the good reproduction and rapid growth of slash pine. This tree, 4 feet above the ground, was $5\frac{1}{2}$ inches in diameter and 9 annual rings were present at that height.
- FIG. 8.—Stand of old timber, such as is rapidly disappearing. This is characterized by having wide sapwood and by producing very high yields under efficient management. Deep chipping (see figure 6) succeeded in this operation.



1



2



3



4



5



6



7



8

fig. 6) is so narrow that it is done in the lightwood. The current prejudice against chipping in the lightwood probably arises from the fact that at times the lightwood (Pl. III, fig. 1), especially when it is most conspicuous, may indicate the beginning of dry-facing. Under such conditions the decreased production occurring may be revived to a certain extent by chipping ahead of this lightwood up the tree for several inches, until a region which is less dried out and injured is reached. It is therefore only when it indicates the saturated condition of dead and dried cells, especially the devitalized condition of the resiniferous parenchyma, that the presence of lightwood should be considered detrimental. Such a condition, moreover, is much more likely to occur in high chipping which is designed to keep ahead of the lightwood than in narrow chipping (one-half inch or less) which is done in the region of the lightwood.

SUGGESTIONS FOR FUTURE PRACTICE.

Many of the statements made in the following discussion are not based upon the results from definite experiments, but are derived from the writer's observations made on successful commercial operations or from the statements of experienced operators, or are deductions from the data presented in the preceding pages. They are, therefore, to be considered as suggestions only and are advanced tentatively, subject to further investigation, because in the light of our present knowledge they appear to be beneficial in character.

SIZE OF THE TIMBER.

From the preceding discussion, especially that with reference to light cupping (pp. 29 to 31), it is apparent that it is unprofitable to turpentine very small timber. An excellent example of conservative operation, from the standpoint of present practice in the United States, is the method specified in the Florida National Forest turpentine leases (page 25).

LOCATION AND SIZE OF THE FACES.

One of the most obvious sources of waste in turpentine operations, and apparently a matter which has received relatively little competent attention, is the matter of placing the faces on the trees. Bad practice of this sort, due to carelessness, is only too commonly found. Figures 2 and 3 of Plate VII, illustrating such bad methods, are in sharp contrast with figure 1 of Plate VII, which illustrates the proper placing of faces. This practice of leaving insufficient bark between faces is a fundamental error of the worst sort, since it means waste throughout the operation. Six-inch, or at least 4-inch bark bars should be left between faces, and the width of face should be in pro-

portion to the size of the tree. (See pp. 29 to 31.) Conservative operators recommend leaving one-half, or at the very least one-third, of the bark uncut. Without such provision the tree is unduly injured and its productive power is reduced so that the yield is less or may even fail entirely, as shown in Plate VII, figure 3. The cost of turpentineing such trees throughout the operation, or until they die, is, however, just as great in the matter of placing cups and aprons, chipping and dipping, as is the cost in the case of the more productive trees. Such trees are also frequently attacked, some think more often than more healthy individuals, by fungus or insects.³⁰ Care is required not only with reference to the position of the faces in relation to each other, but also with regard to the way the tree leans, its general shape or curvature, and any special irregularities which may occur. Loss in production of oleoresin is also occasioned by cutting the first streaks too far above the ground. It is of advantage to place the faces as low as the butt conformation of the tree will permit.

The location of the faces with relation to the points of the compass has received some attention but appears to be considerably influenced by variable local conditions. As is shown in figures 1 to 6, the 15 trees selected at Columbia, Miss., where the position of the faces was noted, showed great variability in wood formation, with some tendency toward greater vigor on the south side. From some experiments with western yellow pine (*Pinus ponderosa* Laws.), it was found that an average from the total yields of 50 trees during one turpentineing season was 9 per cent greater from the south side than from the north side cups.³¹ An experienced operator has advanced the following argument:³²

It is pretty well settled now that the average pine standing erect has thicker sap on the south side, evidence of greater thrift on that side; then, unless there are conditions that require it otherwise, it would seem to promise a larger yield of gum to so install the cup and chip as to leave as much of this best sap uncut as possible. Make the faces west or southwest, east or southeast. In cupping trees of the size to permit two cups, if the timber is to be cut for lumber before it has time to be recupped (or back cupped), place them opposite, east and west; but if it is expected to be cupped the second time, hang the cups southwest and southeast with 6 inches of unchipped surface between.

CONTAINERS FOR THE GUM.

The destructive method of using a box cut in the tree (Pl. I, fig. 1) to hold the gum has been practically abandoned. In its place are found a great variety of containers or cups of pottery or metal.

³⁰ Hopkins, A. D., "The Southern Pine Beetle." Farmers' Bul. 1188, U. S. Dept. Agr., 1921.

³¹ Betts, H. S., "Possibilities of Western Pines as a Source of Naval Stores." For. Serv. Bul. 116.

³² Courtesy of Mr. A. Sessoms, Bonifay, Fla.

Some of these are illustrated in Plate I, figures 3, 5, and 6, and Plate VII, figure 2. They present various advantages and disadvantages. The earthen or clay cups do not rust and discolor the gum as the metal cups that have been used for some time may do, but they are subject to breakage in handling and during freezing weather. Various efforts such as lining metal cups with wood have been made. One of the most successful has been coating old cups with bakelite, which prevents the discoloration of the gum. The argument that the metal cup becomes hotter during warm weather and causes greater evaporation of the gum is advanced by clay-cup advocates. Partly covered cups which reduce evaporation are used in India.

The connection between the cup and the surface of the tree is made by the use of gutters or aprons. (Pl. I, figs. 3 and 6, and Pl. IV, figs 1 and 3.) Efforts have also been made to develop an apronless cup. In order to attach the cups and gutters to the trees, nails are often employed, but these are very undesirable from the point of view of the sawmill end of the operation, for even though they are theoretically all removed, headless or hidden nails may occur and be very destructive if encountered during the process of sawing up the timber. With this in mind, wooden pegs (Pl. IV, figs. 3, 4, and 6) to support the cups or soft lead nails to attach the apron, when the cup is raised, are used by some operators so as to avert possible damage if accidentally left in the tree.

CHIPPING.

Two sizes of hacks are illustrated in Plate IV, figure 2. The hack with the narrow opening or "bill" is a "00," such as was used on the narrow chipping at Columbia, Miss. The other hack is a "No. 2," such as was used on the standard operation by the cooperating company. The method of chipping, a free arm stroke, is illustrated in Plate IV, figure 4. It would be very desirable if a gauged hack could be devised which would mechanically govern the size of the chip cut. The "puller" for cutting a streak on the higher faces is illustrated in Plate IV, figure 6. It is said that "pulling" is more difficult than chipping³³; the use of the 00 hack and narrow chipping defers the time when pulling need be used. With the puller good narrow chipping may be obtained, as in the case of the double chipping at Columbia in 1917. It is thought to be highly desirable to use a sharp tool and to make clean smooth cuts at regular intervals.³⁴ Practically, chipping once in seven days has been found to give satisfactory results. The Columbia, Miss., experiments indicated that chipping twice a week was not desirable for long operations.

³³ For. Serv. Bul. 90, p. 19.

³⁴ In India the smoothness of the face or channel is especially emphasized. The greatest care is taken to remove rough surfaces which would promote the formation of scrape.

DEPTH OF THE WOUND.

The width of the sapwood appears to be very intimately connected with the distance that it is advantageous to cut (radially) into the tree (cf. p. 28). At the present time it can only be stated that a considerable portion of the moist sapwood should be left behind the face. Instances undoubtedly occur in which a very considerable yield of gum may be obtained by making relatively deep cuts, $\frac{3}{4}$ inch to 1 inch into sapwood which is as much as 3 inches wide; for a notable yield has been found to come from the resin passages of a number of the outer sapwood rings (Pl. III, fig. 2), not merely from those formed after turpentineing. Before chipping more than one-half inch in depth, however, the width of the sapwood should be determined. Some operators judge the amount of sapwood and the yielding capacity of the tree by the roughness or loose, scaly appearance of the bark, as contrasted with the relatively smooth bark found on some trees. No consistently dependable characteristic, however, is known for predicting the productivity of a given tree, for individuals are found to show wide variations.

HEIGHT OF CHIPPING.

The amount of wood removed vertically with the grain at each chipping has been very fully discussed in the preceding pages. It is evident that weekly chipping less than one-half inch in height has been found successful both as to yield and with reference to maintaining the productivity of the trees by not unduly reducing their vitality. The lower limit for the height of chipping has not yet been determined, but in the narrow chipping at Columbia, Miss., an average height of 0.34 inch was actually obtained.

ADVANCE STREAK.

The practice of cutting one streak some weeks before regular chipping begins appears to be advantageous (cf. pp. 10 to 12). Regular winter chipping, however, is considered unprofitable. The advance streak is used in India.

JUMP STREAK.

On many operations, when the cups are raised, a section of uncut bark is left (Pl. VII, fig. 3) so that in driving in the aprons the sapwood layer or conductive tissue will not be completely severed. As a consequence, some chipping surface is lost, but this is reduced to a minimum by changing, as the end of the season approaches, the "set" of the peak, or the angle made by the two streaks at the middle of the face, so that the angle is obtuse.

DESIRABLE PRACTICES.

Ideal chipping should be deepest at the shoulder and shallowest at the peak or most exposed portion of the face, at which point the least normal and most harmful conditions, with respect to the vitality of the trees, are most likely to develop.

Keeping the gum clean means high grades of rosin; hence it is well to cover the cup with a paddle during chipping (Pl. IV, fig. 4), or to equip the "puller" with a chip catcher (Pl. IV, fig. 6), to keep fragments of bark out of the gum during chipping and to avoid filling the cups with trash which will increase the apparent volume of the dip.

DIPPING.

Frequent collecting of the gum or dipping insures higher yields of turpentine.³⁵ Some advocate scraping off the hardened gum, or scraping with the paddle at each dipping instead of allowing it to remain until the end of the season and removing it all at once as was done in figure 4, Plate I. It is maintained that the latter practice exposes the surface to undue drying, and that harmful cracking and checking may take place. Furthermore, the longer the scrape remains on the tree the greater is the reduction in the amount of turpentine which it will yield. A real reduction of waste may be obtained by using tight dip barrels. On one operation gasoline barrels were employed. Ideal dip containing about one-third more turpentine than usual was obtained by using closed glass cups for holding the gum as it exuded from the tree, but these were found to be very difficult and expensive to operate.

YIELDS.

It would appear as if under proper operating conditions more gum should be obtained at least during the second and third years than during the first, for many more resin passages are present. This, however, is not ordinarily the case in the United States.³⁶ On the Columbia, Miss., experiment the narrow chipping nearly held its own the second year, but during the first year the total yield, without reference to the amount of chipping surface used, was lower than the yield from the standard.³⁷ It seems entirely possible that an optimum

³⁵ In India dipping is as frequent as chipping. The same worker does both and is paid on the basis of the gum produced. One worker chips (by the French method) about 1,000 faces or channels in 6 days.

³⁶ Since this was written, information has been obtained from Mr. F. Canning, conservator of forests, India, concerning turpentine operations by the French method (very conservative chipping) on *Pinus longifolia* in the Kumaon Hills in the United Provinces, to the effect that, as a rule, more gum is obtained the second, third, and fourth years than the first. The yield the fifth year is about the same as that obtained during the first.

³⁷ Data from the Florida National Forest experiments about to be published are also of interest in this connection.

set of operating conditions may some day be found under which the yields will not fall as markedly as is now usual. It has been held that it is in the fourth year that the reduced response of the turpentine trees is most marked. This also may be further delayed or reduced by practicing better methods.

REDUCING THE NUMBER OF CUPS TO THE ACRE.

By applying the rules laid down for conservative chipping (p. 25) the number of cups per acre would be materially reduced. Often a 50 per cent reduction would assure a higher yield. The argument that the cup system has been bad for the trees, based on the fact that the trees have been overcupped, may be true if one considers such operations as one in which 232 cups were hung to the acre, but such a procedure is unproductive and will not long be practiced by clear-sighted operators. The fact that individual pines will survive under excessively abusive treatment is no indication that high total yields over a period of years may be obtained in this way. There is a case on record, for instance, of a tree 9 inches in diameter 5 feet above the ground which had had two boxes cut in it that were operated for five years. During the third year a cup was also added and the tree continued to produce some gum, although it had all together only 14 inches of live bark between the faces. Again, a tree 6 inches in diameter survived turpentineing and grew fairly well. Such methods, however, are to be deplored for the same reason that it was not desirable to kill the goose which laid the golden eggs.

REPRODUCTION.

Protecting the turpentine trees and the young growing seedlings (Pl. VII, fig. 7) from fire is of importance to the future of the industry. Very important, also, is the protection of the seedlings from destruction by hogs, which appear to prefer the roots of longleaf pine to those of the less valuable loblolly pine.

SUGGESTIONS FOR FUTURE RESEARCH.

There are still many unsolved problems which are of importance from the point of view both of commercial practice and of fundamental scientific knowledge.

Of immediate significance is the question of the proper turpentineing of small timber. The existing second growth, the protected natural reproduction, and the prospective plantations of slash and longleaf pine will be the future source of naval stores. The results presented here were obtained chiefly from large, mature timber. The methods required for the successful turpentineing of young trees should have further study, especially with reference to the depth

of chipping advisable in relation to the width of the sapwood. More information, in addition to the results obtained in the Florida National Forest experiments, is desirable in regard to the relative width of face to employ. Which, for instance, is more costly, and which produces higher yields, the use of two small faces or of one large one, or, on larger trees, two large faces or three small ones? In this connection it is important to determine under what circumstances the peak is kept most healthy and productive, since it is at the peak that dry-facing most often begins. The question of the minimum width of bark bars between faces is fairly well determined, but an innovation in the form of leaving a bark bar in the middle of the face, which is practically equivalent to chipping two small faces, has been suggested.

A detailed study of the length of the normal resin passages and of those formed after wounding, made by dissecting the outer surfaces of logs, would furnish information bearing on the desirable height of chipping, and on the matter of maintaining gum production, at least at the level of that obtained during the first year of the operation.

The effect on yields of resting the timber for a year or for a shorter period of weeks or months at some time during the operation might be significant. In one instance it is reported that timber turpented for two years and rested for a year before continuing the operation gave exceptionally high yields.

More exact information regarding the responses associated with the use of the advance streak is essential in order that this practice should be more fully understood.

The method of using closed cups made it possible to obtain a very high grade of gum, which gave an exceptionally high yield of turpentine, but it was impractical in operation because of the difficulties encountered in freshening the yielding surface and because of the expense of the cups. It seems possible, nevertheless, that some method of covering the cups, such as is used in India, or of protecting the faces or of using borings instead of open faces,³⁸ might be devised. By such means evaporation might be markedly reduced and production notably increased.

It is highly desirable that some of the conclusions recently obtained in German experiments³⁹ should be checked upon American species. The filling and the emptying of the resin passages during turpentering is a problem of fundamental significance. The steps in the process by which the tree manufactures the oleoresin are still practically

³⁸ "To try out the Augur and Glass Holder System." *Naval Stores Review*, 31: June 25, 1921, p. 10.

³⁹ Münch, E.: "Naturwissenschaftliche Grundlagen der Kiefernharznutzung." *Arbeiten a. d. Biol. Forschungsanstalt für Land- u. Forstwirtschaft*, 10 Bd.: 1919.

unknown. A more intimate knowledge of the substances of the greatest significance in resin production—as, for instance, the effects of the constitution of the soil—might have a marked influence on future practice. This has been found to be the case with fruit culture, as a result of the work on the effects of the carbon-nitrogen ratio upon vegetative and reproductive responses.⁴⁰ Indeed, as has been suggested by Dr. W. D. Bancroft, chairman of the division of chemistry and chemical technology of the National Research Council, who selected oleoresin production as an example of an important present-day problem, the understanding of this subject appears to involve cooperative work by a botanist, a microscopist, an organic chemist, and a colloid chemist. Much valuable information on oleoresin has already been collected by the Bureau of Chemistry and by different units of the Forest Service, and with the timber on the Florida National Forest available for experiment, the opportunities for carrying on further research are exceptionally good. That the future need in this direction is recognized and that plans (in the carrying out of which microscopically obtained data can unquestionably be of service) are being formulated, is indicated in the following statement of Col. W. G. Greeley, Forester:⁴¹

One of the things which must be worked out as part of our general progress in forest conservation is a system of extracting gum turpentine which will make this industry and its valuable commercial products a permanent resource of the Southern States. We must develop a plan for tapping second-growth timber, somewhat along the lines used in France but adapted to commercial requirements in the United States, under which this can be a continuous forest industry, obtaining yields of gum from the same trees for 20 or 30 years, right up to the time when they are cut and converted into lumber. Without some method of this nature the gum turpentine industry will soon cease to exist. I am hopeful that the Forest Service can extend the instructive experiments in various methods of conservative chipping and cupping which you⁴² have already initiated on the Florida National Forest in order to work out completely a plan of tapping second-growth timber without injury which can be adopted commercially by the owners of pine land throughout the South.

SUMMARY.

The results of this work and of the other earlier and current experiments of the Forest Service clearly demonstrate that those methods which conserve the vitality of the tree and its responsive power, under stimulation such as is given by turpentineing, insure the greatest production of oleoresin. The process of turpentineing is not merely a draining out of the gum already formed; it is a collection of the oleoresin constantly being manufactured by the tree.

⁴⁰ Kraus, E. J., and H. R. Kraybill, Oregon Agric. College, Exper. Station. Bulletin 149, 1918.

⁴¹ For. Serv. Bul., Jan. 3, 1921.

⁴² That is, Florida National Forest organization.

This production of gum by the tree is greatly increased as a result of the stimulation of the wound or face cut.

The institution of cupping, in place of boxing, made it possible to eliminate the unnecessary injury to the tree caused by cutting the box, and hence was a marked advance in the direction of improved operation.

The proper placing of faces with reference to the size and conformation of the tree, and the maintenance of bark bars of sufficient width between faces, are matters of fundamental importance, which too often are neglected in practice. These matters if not cared for involve waste and loss throughout the operation.

The fact that it is unprofitable to turpentine too small trees, at least by present commercial methods, has been demonstrated beyond question.

The practice of cutting a streak in advance of the regular season's chipping on a virgin or first year operation appears to be productive of an increased early yield, which is of practical importance. This effect, as has been clearly shown, is not produced by the induced resin passages, formed at once as the immediate result of the streak, but presumably is due to the wound stimulus given to the resiniferous tissue already present.

The following effects of turpentine on the structure of the wood have been pointed out:⁴³

The structure of the annual rings of the wood formed before turpentine was not found to be visibly affected as a result of the turpentine, although the activities and responses of the living parenchyma cells in the outer layers of the sapwood already present in the immediate vicinity of the wound were undoubtedly stimulated by it. It was demonstrated that the resin passages of a considerable number of these outer sapwood rings contributed a very significant portion of the yield of oleoresin.

The structure of the wood produced after wounding was considerably modified, especially in the region immediately above the face. The effect in a tangential or circumferential direction was relatively slight, being hardly noticeable at a distance of 2 or 3 inches to the side of the wound. In all material the number of resin passages formed was greatly increased. The resin passages were formed earlier in the ring than normally. They varied from about the same diameter as that of the normal resin passages to rarely larger and frequently smaller diameters. The response to the wound stimulus, particularly in respect to the increased number of resin passages formed, was observed to be greatest within about 1 foot above the

⁴³ See also Gerry, E., "Proper Methods of Turpentineing," *Sci. Am. Sup.* 2176, Sept. 15, 1917; and Gerry, E., "Production of Crude Gum by the Pine Tree," *Naval Stores*, p. 147, 1921.

wound. It was also registered in the wood produced 6 to 9 feet vertically above the wound. At this point the resin passages were fewer than near the streak, but, nevertheless, were more numerous than in the round timber. The resin passages in the specimens studied were observed in both the open and closed condition, as is shown in the illustrations. Although this increased number of the resin passages, formed after wounding, is an important factor in securing a high yield, they are not, as has been shown, the only or possibly even the chief source of the gum.

Provided the size of the timber and the faces and their location have been properly cared for, the method of chipping which is intimately connected with these features is also of fundamental significance. Characteristic effects on the structure of wood, resulting from different methods of chipping, were determined and fully described in the discussion of the microscopic investigations made.

HEAVY CHIPPING.

Heavy chipping (more than one-half inch in height and more than three-fourths inch in depth) or overcupping tends to produce the following undesirable results in the wood formed after turpentinizing.

1. Delay in the beginning of wood formation.
2. Delay in the formation of resiniferous tissue.
3. Reduction in width of annual rings.
4. Reduction in amount and thickness of walls of the summer wood.
5. Tendency to develop resiniferous parenchyma at the expense of other wood cells.
6. Death of a relatively high percentage of trees and tendency to produce dry-face.
7. Markedly reduced yield from year to year.

CONSERVATIVE NARROW CHIPPING.

Conservative chipping, of which the narrow, as practiced at Columbia, Miss., is an example, produced results in direct contrast to those from heavy chipping. The optimum methods of turpentinizing are still to be determined, but in the light of our present knowledge, the application of the following specifications would appear likely to produce the nearest approach to ideal operation that has thus far been attained.

No tree under 10 inches in diameter, breast high, should be cupped.

One-half, or at the very least one-third, of the total circumference in the neighborhood of the faces should be covered with uncut bark. Bark bars, at the minimum about 6 inches wide, should be left between faces.

Chipping should progress up the tree at the rate of not more than one-half inch a week. In experiments in which chips of an average height of 0.40⁴⁴ to 0.34⁴⁵ inch were actually cut, a higher sustained yield was produced than in comparable workings in which the chip averaged one-half inch high. In the case of the double chipping at Columbia, Miss., an average height of chip of 0.32 inch was obtained with a 00 hack in 1916, and an average 0.26-inch chip with a puller during 1917. During the second year these trees, under this treatment, showed a smaller relative reduction in yield of turpentine, when compared to the first year yield, than did the half-inch chipping (standard). Using such a narrow streak means chipping in the lightwood or region of maximum stimulation, at least for a part of the season. It is yet to be determined whether the height of the chip can be further reduced.

Sufficient experiments to determine the most advantageous depth of chipping have not been carried out. It appears probable that the significant factor in this case, however, is the width of the sapwood, since, as has been shown, a considerable yield is obtained from many of the outer sapwood rings. A layer of healthy moist sapwood should always be present behind each face to maintain at the maximum the vital activities of the sapwood layers exposed at the streak. With wide sapwood and deep chipping (about three-fourths inch) very high yields may be obtained.

The advantages to be gained by the practice of conservative narrow chipping were shown to be the following:

1. Higher yields (40 to 50 per cent) per inch of height of chipped surface.
2. Higher sustained yields—that is, less reduction in yield from year to year, approaching the optimum condition, confidently to be expected, when the yields of subsequent years will surpass that of the first year.
3. Total annual yield approximating or even surpassing the yield from heavier chipping.
4. Little reduction, on the average, below the wood formation of the round timber, either in amount or quality.
5. Very high production of resiniferous tissue. This, for a given year, was markedly greater about one foot above the early streaks made that year. Hence narrow chipping enables the operator to reap the full benefit from this region of maximum stimulation and response by the practice known as chipping in the lightwood instead of wasting the wood containing the greatest number of resin passages by cutting it away with high chipping.

⁴⁴ Early Forest Service Experiments, page 27.

⁴⁵ Narrow chipping, Columbia, Miss., page 21.

6. Low rate of death of trees from turpentine and the production of few dry faces, hence less degrade of lumber due to pitch saturation or to infection at the face area.

7. Responsive vigor not reduced, as is shown by (*a*) the early formation of wood and resiniferous tissue; (*b*) the increases in diameter growth found even under turpentine; (*c*) the formation of the summer wood, which also occurred earlier in the narrow than in the standard and double chipped timber at Columbia, Miss.; and (*d*) a relatively very high total production during the second year of operation, especially since this was sustained as is shown, for instance, late in the season even after a severe drought, when neighboring crops showed a comparatively poor exudation of gum.

8. Greater ease in operating, once the chipper becomes accustomed to the method, since less wood is removed and the chipping period can be prolonged and the pulling period deferred, because the amount of surface chipped yearly is less.

FREQUENCY OF CHIPPING.

From the results obtained with the double chipping at Columbia, Miss., it was concluded that the yield obtained did not show a sufficient increase to offset the additional cost in the case of turpentine operations lasting for a considerable number of years. For a very short operation, when it is planned to turpentine for a period of perhaps two years before cutting the timber, double chipping might possibly be practiced regularly, or perhaps with greatest advantage for a limited period during the height of the producing season. The microscopic study of the material from the double tract showed that this method exerted a decidedly detrimental influence on wood formation and on the general vitality of the timber; and that it used up chipping surface to the same extent as ordinary commercial practice.

STANDARDS FOR ESTIMATING THE EFFECTS PRODUCED BY DIFFERENT METHODS OF CHIPPING.

In estimating the responses of the timber turpentine by the various methods of operation used at Columbia, Miss., the wood formation, especially the width of ring and the amount of summer wood produced by unturpentine trees growing in the same locality under the same conditions, was determined as a basis for judging the effects of turpentine on the wood structure. The best diameter growth and summerwood formation for the three years 1915, 1916, and 1917, were found in the round timber in 1916. Hence marked decreases in the wood formation of the turpentine timber for that year could be attributed directly to the effect of the wounding. De-

creases in 1917 were less indicative, but increases were more significant, since normal diameter growth was relatively low in that year.

It was observed that, regardless of the method used, the response, after turpentineing, of trees with very narrow annual rings often was to produce much wider rings than before; whereas the trees with exceedingly wide rings and very heavy summer wood often showed marked reduction in the wood formed after turpentineing.

A tendency toward more vigorous responses was observed on the south side of trees, as contrasted with the north side.

Very great variation in wood formation and productive power was observed in individual trees in the same environment. No satisfactory means was found, however, of positively determining in advance the productive power of a tree. Marked variations in the wood formation on different sides of a tree, at different parts of the streak, and at different heights, were noted. The study of specimens obtained month by month at different heights was therefore more enlightening in many respects than observations made only at the end of the season.

MISCELLANEOUS OBSERVATIONS.

No consistent relation between width of ring and number of resin passages resulted from an analysis of the data available on this subject.

No indication of a structure corresponding in any way to the "resinogene Schicht" of Tschirch was observed.

The first formation of wood in the region of the trunk where turpentineing is carried on was observed, in 1916 and 1917, to take place not earlier than April 8 to 10; and from that time on in different trees it continued until by the middle of May it had begun in practically all trees. Wood cells or tracheids for the most part formed before resiniferous tissue.

The first formation of resiniferous tissue occurred between the middle of April and the end of May.

Finally, turpentineing gives an additional product and profit from the forest before the trees are cut into lumber. This gain may be obtained, at least in the case of well-managed, large, mature timber, without reducing its strength, or appreciably degrading the lumber. The inch or so of the outer sapwood involved in the process of turpentineing is removed in the slabs and edgings when the logs are cut up. Poor turpentineing methods which kill or dry-face the timber, may produce some degrade due to pitch-streak formation, decay, or excessive insect attack, but this is for the most part unnecessary. The fact that many lumber companies are turpentineing their own timber is also a pertinent argument for the practice.

Turpentining a given tract should, however, be planned far enough in advance of the cutting of the trees to insure the obtaining of the full advantage of at least a four to six year operation, instead of the sawmill demand forcing the timber to be cut at the height of its gum-producing power.

Many other problems, involving the further development of needed improvements in practice, and also many related to a better understanding of the imperfectly known physiological processes fundamental to oleoresin production, await investigation.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1065

Contribution from the Bureau of Markets and
Crop Estimates
H. C. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

May 18, 1922

THE TEST WEIGHT OF GRAIN: A SIMPLE METHOD OF DETERMINING THE ACCU- RACY OF THE TESTING APPARATUS.

By E. G. BOERNER, *In Charge of Grain Investigations*, and E. H. ROPES,
formerly Specialist in Grain Investigations.

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TEST WEIGHT PER BUSHEL AND APPARATUS FOR TAKING IT.

The "test weight per bushel" is one of the governing factors in assigning grades to grain. It is therefore highly essential that the "test weight" be accurately determined, as it affects market values.

The "weight-per-bushel tester," shown in figure 1 and described in United States Department of Agriculture Bulletin 472, was designed by the Department of Agriculture to provide means by which the "test weight per bushel" of grain might be rapidly and accurately determined. This apparatus and the method of use there described have been adopted as the standard apparatus and method in connection with the enforcement of the United States grain standards Act.

The term "test weight per bushel" as applied to grain is a grading designation used in the official grain standards promulgated by the Secretary of Agriculture under authority of the United States grain standards Act. The meaning of the term "test weight per bushel" should not be confused with the meaning of the term "legal bushel," which is used in connection with the United States customs and for commercial purposes, as these two terms are fundamentally different in meaning. Test weight per bushel is the weight of the volume of

grain required to fill level full a Winchester bushel measure of 2150.42 cubic inches capacity. The legal bushel is based on weight instead of measure or volume. For each of several grains a fixed number of pounds is considered a legal bushel; for example, for wheat 60 pounds constitutes a legal bushel; corn, rye, and flaxseed, 56 pounds; barley 48 pounds; and oats 32 pounds.

The standard Winchester bushel measure contains 32 quarts, whereas the actual volume in quarts of a legal bushel of grain de-

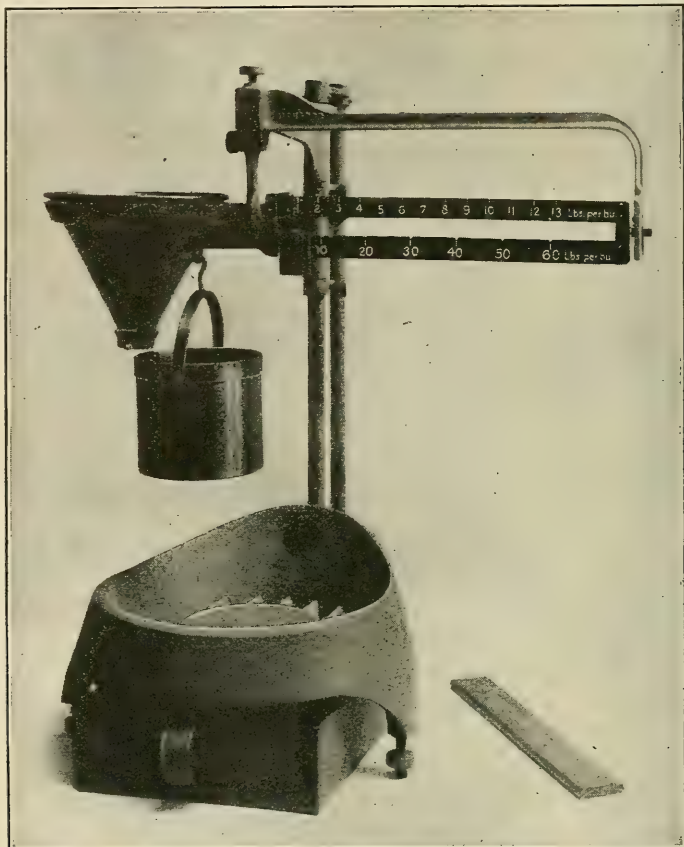


FIG. 1.—Standard apparatus for determining the test weight per bushel of grain.

pends upon its test weight. This is illustrated in figure 2. The volume in quarts required for a legal bushel by weight may be determined by multiplying the legal weight per bushel by 32 and dividing that product by the test weight per bushel of the grain in question. For example, the legal weight of wheat being 60 pounds for a bushel and the test weight of the wheat in question being 50 pounds, how many quarts will be required to weigh 60 pounds? Solution: Multiply 60 by 32 and divide by 50, as follows: $60 \times 32 = 1920 \div 50 = 38.4$ quarts, the volume required to weigh 60 pounds or a legal bushel

of wheat for commercial purposes. The chart in figure 3 shows graphically the number of quarts of grain for various test weights required to weigh the number of pounds fixed by law as a bushel for various grains.¹

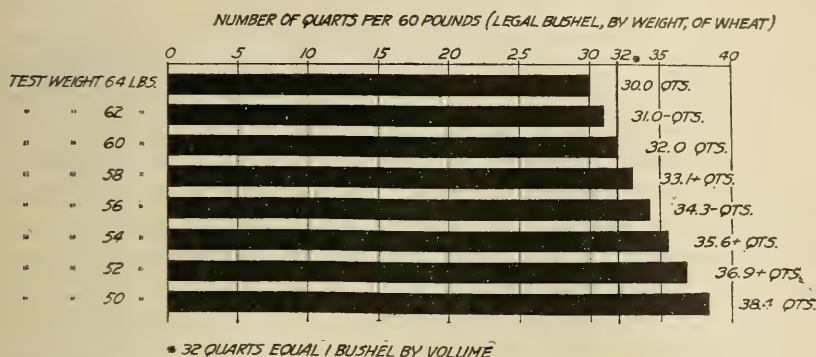


FIG. 2.—Comparison of the volume of 60 pounds of wheat of various test weights.

The standard weight-per-bushel tester is so designed that when the kettle is properly filled and struck off it contains exactly 1 dry quart,

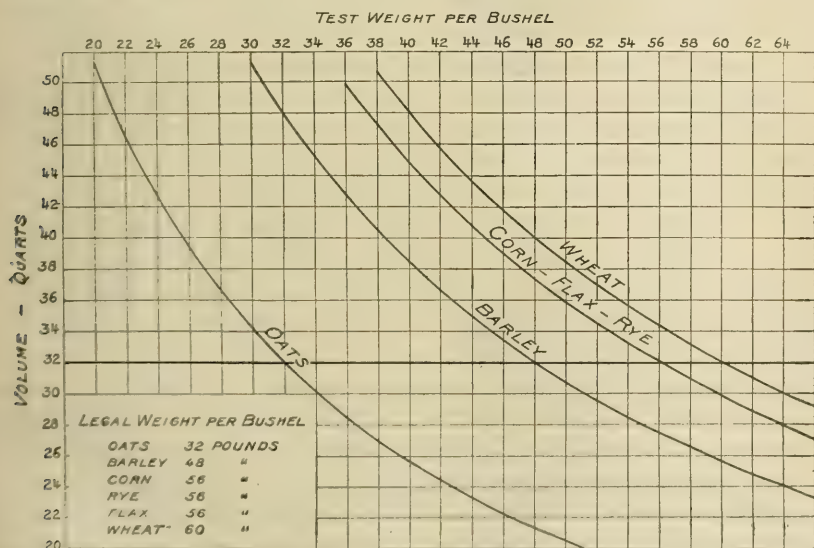


Fig. 3.—The number of quarts, by measure, of grain of various test weights required for a "legal bushel" by weight.

or 67.2 cubic inches. When the filled kettle is hung on its proper hook on the short end of the beam of the official testing apparatus,

¹ Milling and baking tests conducted by this bureau and by other authorities have furnished conclusive proof that 60 pounds of wheat which has a high test weight per bushel, say 60 pounds, will yield more flour of better quality than can be obtained from 60 pounds of wheat which has a lower test weight per bushel, as for instance, 48 pounds.

the weight of its contents may be determined directly in terms of pounds per bushel by means of the counterpoise and the graduations on the beam. As there are 32 quarts to the bushel, the beam is graduated to indicate 32 times the actual weight of the contents of the kettle; therefore, 1 pound in the kettle is equivalent to 32 pounds per bushel on the beam, 1 ounce to 2 pounds, $\frac{1}{2}$ ounce to 1 pound, etc. When these facts are borne in mind the necessity for great care in following the prescribed method in making the weight-per-bushel test and for having an accurate kettle and beam will be realized.

The apparatus for determining weight-per-bushel tests shown in figure 1 and the method of making the test have been carefully developed and are officially approved. It has been demonstrated that if the prescribed method is followed and the apparatus is accurate, weight-per-bushel determinations can be made rapidly and accurately by any one familiar with the test. The two main factors affecting the accuracy of "test weight" determinations are the method used in making the test, and the accuracy of the apparatus. Whether or not the proper method is used depends entirely upon the person making the test, as the official method is clearly defined, but the most careful application of the prescribed method will not give accurate results if the apparatus used in making the test is insensitive or incorrect. The accuracy of the apparatus depends first, upon the capacity of the test kettle, and second, upon the correctness of the weighing mechanism. If the apparatus is purchased from a reliable manufacturer both the kettle capacity and the beam are usually accurate when it leaves the hands of the factory inspector, but even if it is absolutely correct at that time, it may not be correct when set up in the office or laboratory. No test-weight device should be used for determining grades of grain until it has been checked for accuracy by a properly conducted test, and this test should be repeated periodically as a general precaution. In addition to the periodic tests a special test should be made whenever the device has been shipped and particularly whenever any deformation of either kettle or beam is noticed. Any kettle or beam which has been deformed by bending or denting enough to render such deformation visible should be considered incorrect until a thorough test has been made.

Methods of checking the capacity of the standard quart test kettle and the accuracy and sensitiveness of the beam have been developed and are given on pages 8 and 11.

When the test weight per bushel of grain is determined with the standard apparatus in correct adjustment and with careful application of the correct method of use, uniform results are obtained.

VARIATIONS IN MAKING WEIGHT-PER-BUSHEL DETERMINATIONS.

Any variation from the standard apparatus or the standard method of making the test may, and often does, result in an inaccurate

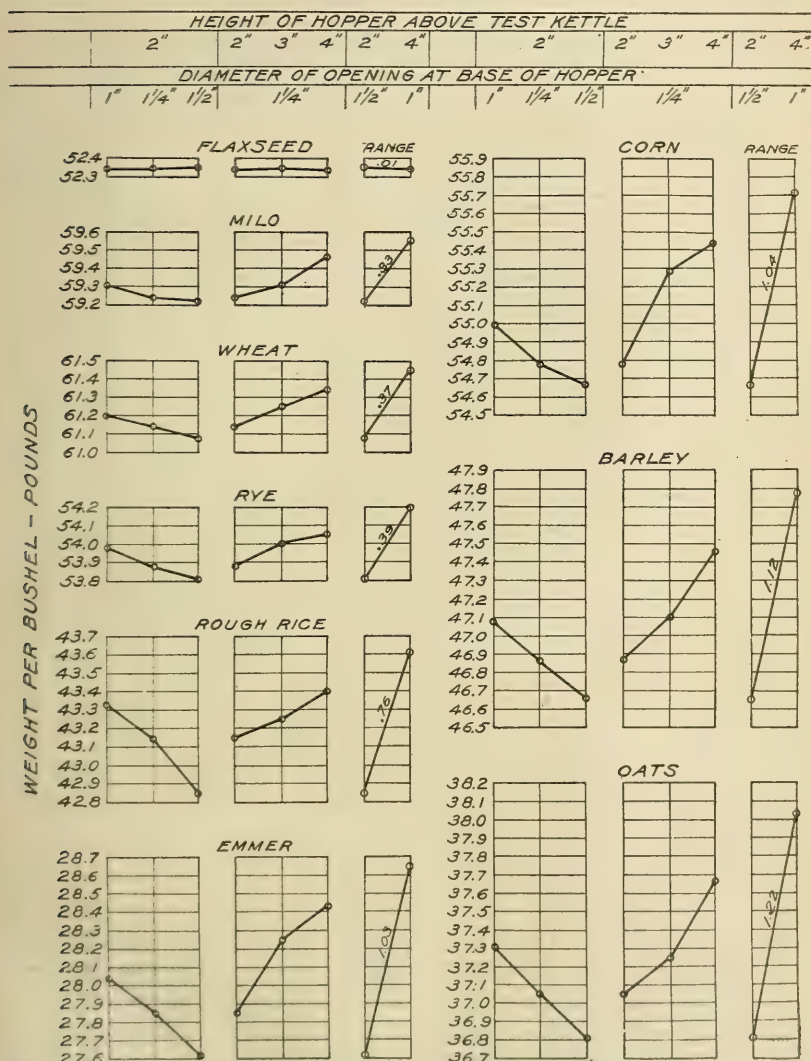


FIG. 4.—The test weight of grain is affected by the height of fall from the filling hopper and the size of the grain stream used in filling the test kettle.

rate test weight. Errors in the test weight may result from any of the following variations:

1. A tester having a beam that is inaccurate, insensitive, or "slow," or having a kettle that is dented, bent, or worn, or a kettle of 1 pint,

2 quarts, or 4 quarts capacity in place of the standard quart-size kettle.

2. A kettle having rough edges on top instead of smooth edges, which cause the stoker to jar the kettle and the grain in the kettle to settle down during the stroking operation.

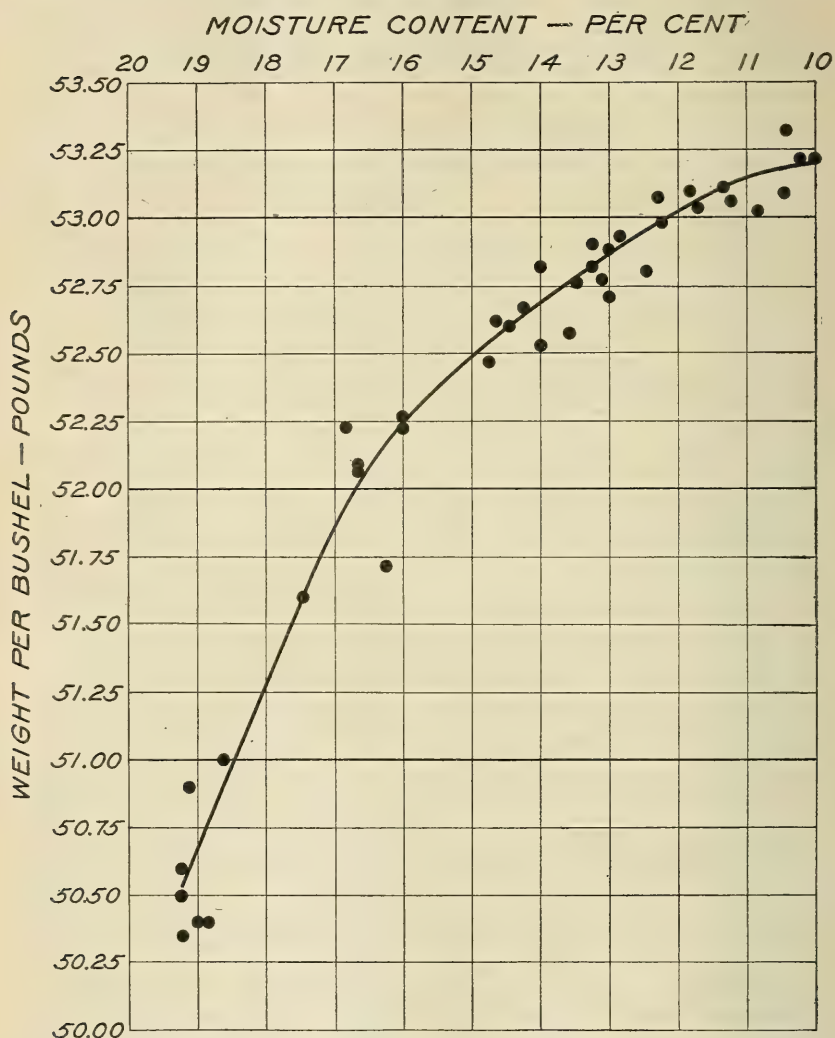


FIG. 5.—The influence of moisture content on the test weight of corn. This illustrates the necessity of making the weight-per-bushel test immediately after the samples have been delivered to the inspection or testing room.

3. Instead of having the kettle rest on a firm base and filling it from a standard hopper, it is pulled through the grain until it is full; or it is sunk part way into the grain and filled by pulling the grain over the edge by hand; or it is filled by a few handfuls and

sometimes by several small handfuls; or it is filled from a pan or bag or from a funnel not of standard design.

4. The bag, pan, or funnel in some cases is held at a point either higher or lower than 2 inches above the top of the kettle, sometimes almost even with the top and at other times raised to a considerable height above the kettle; or it is filled from such bag, pan, or funnel sometimes with a thin small stream and at other times with a large heavy stream. (See fig. 4.)

5. Instead of striking off the excess grain with the standard stroker, the grain is struck off with the scalebeam, a sawed-off piece of broomstick, a pencil or other implement, or with a worn-out standard stroker having rough edges.

6. The kettle is tapped or jarred before the surplus grain is struck off; or the grain is pressed into the kettle before it is stroked off; or when the standard stroker is used, the stroke is not made with three full-length motions; or the stroker is held inclined forward or backward instead of vertically; or the stroker is allowed to jar the kettle when it is placed in position; or it is held pressed too tightly against the kettle during the stroke, thereby causing a jarring of the kettle.

7. In the case of wheat, the test, instead of being made on the dockage-free wheat, which is the correct method, is made on wheat containing the dockage.

Allowing samples having a high moisture content to lie around and dry out for some time will also seriously affect their test weight, as is shown in figure 5.

TABLE 1.—*Variations in the test weight per bushel of oats obtained by filling the test kettle by different methods.*

Test kettle filled—	Weight per bushel (pounds).							
	Individual tests.					Mini- mum.	Maxi- mum.	Aver- age.
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.			
From a bag held 2 to 3 inches above the kettle.	37	37.5	37.5	38.25	37	37	38.25	37.45
By sinking it into the grain and pulling the grain into the kettle by hand:								
(1) By one motion of both hands.....	36.5	36.5	36.5	36.5	36.25	36.25	36.5	36.45
(2) By 9 to 11 motions of both hands.....	37	37	37	36.75	37	36.75	37	36.95
By dipping it into the grain.....	38.75	39.25	39	39.5	39.5	38.75	39.5	39.20
By pulling it through the grain with about a 2-foot sweep:								
(1) Through loose, worked-over grain....	38	38.25	38.25	38.25	39.5	38	38.5	38.45
(2) Through the packed surface of the grain in a car before the grain had been worked over.....	39.75	40.75	39.5	39	39.75	39	40.75	39.75
From a hopper having an outlet opening 1½ inches in diameter held 2 inches above the kettle (official method).....	37.2	37.2	37.3	37.2	37.2	37.2	37.3	37.22

SPECIAL POINTS TO OBSERVE IN MAKING CORRECT WEIGHT-PER-BUSHEL TESTS.

1. Use an accurate quart-size weight-per-bushel testing apparatus.
2. Fill the kettle from a hopper.
3. The opening at bottom of hopper must be round and exactly $1\frac{1}{4}$ inches in diameter.
4. The bottom of the hopper must be held exactly 2 inches above the center of the kettle.
5. Mark the hopper on the inside at a point where it will hold just enough grain to cause an overflow over all sides of the kettle.
6. Use the same volume of grain for each test.
7. Use a stroker made of hardwood, with smooth rounded edges, 12 inches long, $\frac{3}{8}$ inch thick, and $1\frac{3}{8}$ inches broad.
8. Place the stroker on the edge of the kettle lightly without jarring the kettle.
9. Hold the stroker on the kettle with its sides in a vertical position.
10. Stroke the grain from the kettle with three full-length zigzag motions of the stroker.
11. Make the stroke clean all the way across the kettle.
12. Have the kettle rest on a firm base.
13. Do not jar the kettle before or during the stroking operation.
14. If the top of the kettle is rough, smooth down the roughness with a rounded metal bar but do not use a file.
15. Make the test immediately after the sample has been brought to the inspection room, office, or laboratory, to prevent the grain from drying out with consequent change in test weight.
16. In the case of wheat and other grains for which the standards provide a specification for "dockage," make the test after the dockage has been removed.
17. The quart kettle must have a capacity of exactly 67.2 cubic inches.
18. Use a beam which is both accurately graduated and sensitive to $\frac{1}{10}$ pound per bushel.
19. Have the grain tester tested periodically for—
 - (a) Accuracy of kettle capacity;
 - (b) Accuracy of beam readings; and
 - (c) Sensitiveness of beam.

Any office of Federal grain supervision will be glad to test any apparatus for accuracy, or arrange to have it tested free of charge.

METHOD OF DETERMINING ACCURACY OF TEST KETTLE.

Apparatus required: (See fig. 6.)

1. Kettle to be tested.
2. Slicker plate, plate glass 5 inches in diameter.

3. A correct even-arm balance.
4. One standard weight weighing 1,098.08 grams, or standard weights from which this amount can be built up.
5. One tolerance weight (1 gram).
6. A supply of distilled or pure water.
7. A chemical thermometer reading 20° C. or 68° F.

To make the test:

1. Remove scoop from balance and place the test kettle, slicker plate, and standard weight on scoop bracket and bring the scale to exact balance by means of weights and sliding poise, as shown in figure 7.

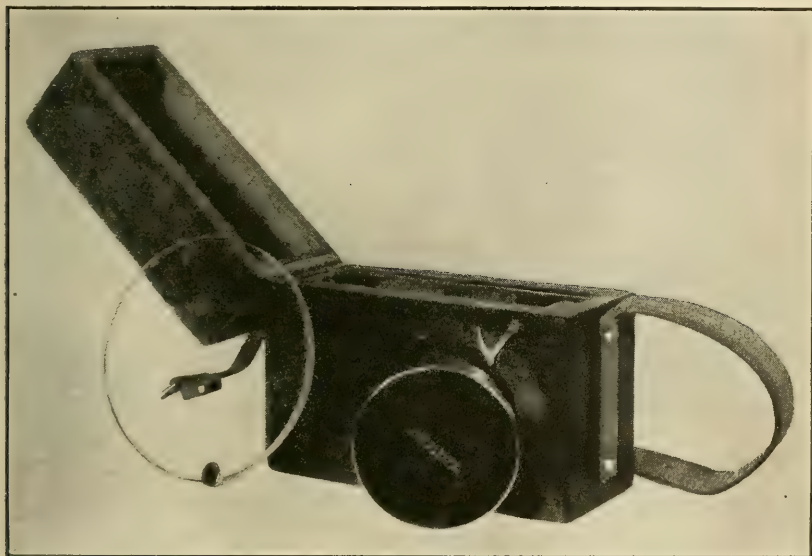


FIG. 6.—Special apparatus consisting of a metal weight weighing 1,098.08 grams, glass, slicker plate, and a 1-gram tolerance weight used in connection with a sensitive even-arm balance for determining the accuracy of quart weight-per-bushel testing kettles.

2. Remove kettle, slicker plate, and standard weight from one arm of the balance, being careful to avoid disturbing the weights or counterpoise on the other arm of the balance. Fill the kettle full to overflowing with distilled water which has been brought to the required temperature of 20° C. or 68° F. and place slicker plate on top of kettle to remove excess water, leaving the kettle exactly level full. The purpose of this action is similar to that of "striking-off" the excess grain in a test kettle when making a weight-per-bushel test. To eliminate all air bubbles from beneath the plate and the inside of the kettle it may be necessary to repeat this operation several times, refilling the kettle each time. When there are no air bubbles in the kettle carefully wipe off all moisture on outside and bottom of kettle.

3. Replace kettle filled with the distilled water and covered with the slicker plate, omitting the standard weight, on scoop bracket of balance without spilling water or disturbing weights previously set, release the arrest or damper, and let the pointer on balance come to rest.

4. If when the pointer has ceased oscillating it indicates an exact balance, the capacity of the kettle is correct and this test is satisfactorily completed.

5. If the pointer comes to rest at any other position than the center of the graduated arc, or center of balance, place the tolerance

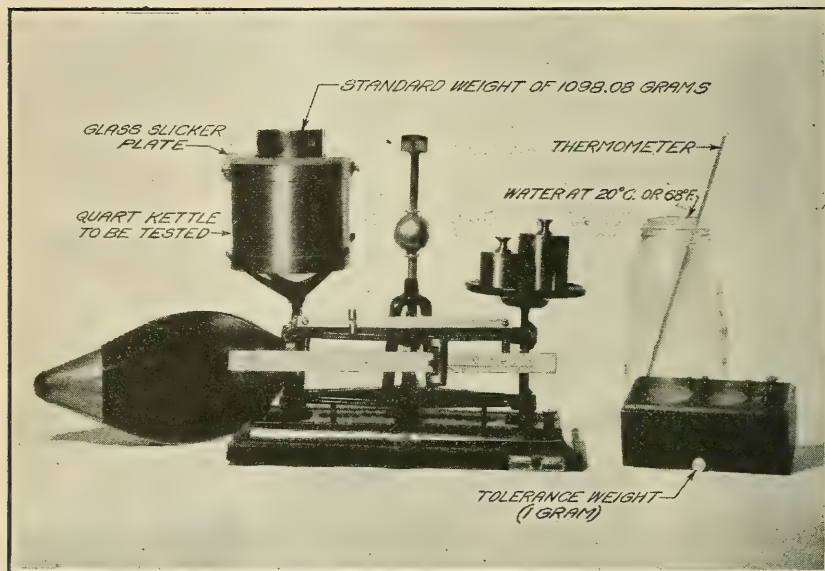


FIG. 7.—Apparatus required for determining the accuracy of the quart-sized kettle. The standard weight shown on top of the glass slicker plate over the test kettle is equal in weight (1,098.08 grams) to 1 quart of water at 20° C. (68° F.).

weight (1 gram) on the light side of the balance. If the tolerance weight is sufficient to swing the pointer to or across the center mark, the error in kettle capacity is within the allowable tolerance and the kettle may be used. But should the tolerance weight be insufficient to swing the pointer to the center of its arc, or bring the scale to balance, the error in the kettle capacity exceeds the allowable tolerance and the kettle should not be used in making official tests.

To insure a correct test it is of course essential that the balance used in making the test be sufficiently sensitive to indicate a change in the pointer or beam reading when the tolerance weight is added to or taken from either arm of the loaded balance.

METHOD OF DETERMINING ACCURACY AND SENSITIVENESS OF BEAM.

Before attempting to check the accuracy of the beam the base of the tester should be leveled and, if it is of the standard type with horizontal arm and trig loop, this level should be tested by examining the position of the projection or pointer on the end of the beam in its relation to the trig loop. The pointer should be in the center of the trig loop both horizontally and vertically when the empty kettle is on the beam and the counterpoises are at zero. If this is not the case the leveling screws should be adjusted until it is true.

There are two methods of checking the accuracy of the beam graduations. In the more simple and direct method a special set of 14 accurate testing weights is used while in the other method an ordinary set of metric weights is used.

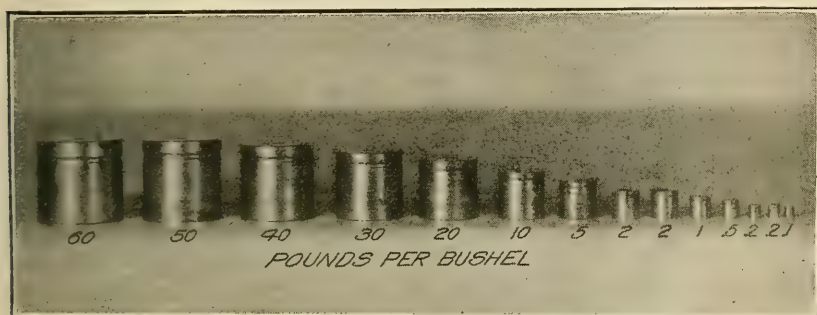


FIG. 8.—Special weights used in determining the accuracy of the beam in the weight-per-bushel testing apparatus. In making the test these weights are placed in the test kettle.

The 14 special weights illustrated in figure 8 are marked to represent the following number of pounds per bushel: 60, 50, 40, 30, 20, 10, 5, 2, 2, 1, 0.5, 0.2, and 0.1. Each weight actually weighs $\frac{1}{32}$ of its marked value. To test the beam place any weight or combination of weights, within the range of the beam graduations, in the kettle and bring the beam to balance by means of the counterpoise. The combined readings of the counterpoises should now equal the combined represented weights in the kettle, and the difference between the weight represented in the kettle and on the beams, if any, is the error of the beam.

It is equally essential in making correct weight-per-bushel tests, especially on "line" samples, that the beam should not only indicate an apparently correct reading when a given weight is placed in the test kettle but that it should also be sensitive to within one-tenth of a pound per bushel. That is, the beam should be sufficiently sensitive to move either up or down noticeably, and in the case of a

tester having a trig loop the beam should move from the center position to either the top or the bottom of the trig loop whenever the poise on the beam is shifted one-tenth pound under or over the correct position for the load that is being weighed in the test kettle. Beams are occasionally found in use which are "slow" and which do not show a change in the beam reading until the poise is moved along the beam often to the extent of an indicated half pound or more per bushel.

In testing the beam by the second method, an accurate set of ordinary metric weights, comprising weights from 1,000 grams to 0.1 gram, is used. However, if 0.1 gram weights are not available, 1 gram weights may be used to check to within one-tenth of a pound per bushel.

The table of equivalents (Table 2) has been prepared to facilitate the use of metric weights for checking beams.

HOW TO USE THE TABLE OF EQUIVALENTS.

It must be remembered that the pounds per bushel in the table are shown on the beam of the tester, and that the equivalent grams per quart in the table are to be placed in the kettle. The first column in the table contains the even pounds per bushel and the second column headed "0.0" (tenths) contains the grams-per-quart equivalent. The third column headed "0.1" contains the grams-per-quart equivalent to the pounds per bushel horizontally opposite any gram figures plus 0.1, or in the last column headed "0.9" the figures in grams horizontally opposite to any pounds per bushel in the first column represent that number of pounds plus "0.9."

Example: How many grams per quart are equivalent to 50.9 pounds per bushel?

Follow down the left-hand column of the table to 50.0, then on that line horizontally to the right to the column headed 0.9 and find 721.5 grams, which if placed in the kettle should balance 50.9 pounds per bushel on the beam.

If it is practicable to determine the weight in grams of the contents of a quart test kettle, this weight per quart in grams may be transposed by the use of the table to pounds per bushel.

Example: If 1 quart of grain is found to weigh 781 grams, what is the weight per bushel?

Find 781.0 grams in the column headed 0.1. It is horizontally opposite 55.0; therefore, 781.0 grams per quart is equivalent to 55.1 pounds per bushel.

TABLE 2.—Grams per quart equivalent to pounds per bushel.

Pounds per bushel.	Tenths of pounds per bushel.									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	Grams per quart.									
0.....	0.0	1.4	2.8	4.2	5.7	7.1	8.5	9.9	11.3	12.8
1.....	14.2	15.6	17.0	18.4	19.8	21.3	22.7	24.1	25.5	26.9
2.....	28.3	29.8	31.2	32.6	34.0	35.4	36.8	38.3	39.7	41.1
3.....	42.5	43.9	45.4	46.8	48.2	49.6	51.0	52.4	53.8	55.3
4.....	56.7	58.1	59.5	60.9	62.4	63.8	65.2	66.6	68.0	69.5
5.....	70.9	72.3	73.7	75.1	76.5	78.0	79.4	80.8	82.2	83.6
6.....	85.0	86.5	87.9	89.3	90.7	92.1	93.5	95.0	96.4	97.8
7.....	99.2	100.6	102.1	103.5	104.9	106.3	107.7	109.1	110.6	112.0
8.....	113.4	114.8	116.2	117.6	119.1	120.5	121.9	123.3	124.7	126.2
9.....	127.6	129.0	130.4	131.8	133.2	134.7	136.1	137.5	138.9	140.3
10.....	141.7	143.2	144.6	146.0	147.4	148.8	150.2	151.7	153.1	154.5
11.....	155.9	157.3	158.8	160.2	161.6	163.0	164.4	165.8	167.3	168.7
12.....	170.1	171.5	172.9	174.3	175.8	177.2	178.6	180.0	181.4	182.8
13.....	184.3	185.7	187.1	188.5	189.9	191.4	192.8	194.2	195.6	197.0
14.....	198.4	199.9	201.3	202.7	204.1	205.5	206.9	208.4	209.8	211.2
15.....	212.6	214.0	215.5	216.9	218.3	219.7	221.1	222.5	224.0	225.4
16.....	226.8	228.2	229.6	231.0	232.5	233.9	235.3	236.7	238.1	239.5
17.....	241.0	242.4	243.8	245.2	246.6	248.1	249.5	250.9	252.3	253.7
18.....	255.1	256.6	258.0	259.4	260.8	262.2	263.6	265.1	266.5	267.9
19.....	269.3	270.7	272.2	273.6	275.0	276.4	277.8	279.2	280.7	282.1
20.....	283.5	284.9	286.3	287.7	289.2	290.6	292.0	293.4	294.8	296.2
21.....	297.7	299.1	300.5	301.9	303.3	304.8	306.2	307.6	309.0	310.4
22.....	311.8	313.3	314.7	316.1	317.5	318.9	320.3	321.8	323.2	324.6
23.....	326.0	327.4	328.8	330.3	331.7	333.1	334.5	335.9	337.4	338.8
24.....	340.2	341.6	343.0	344.4	345.9	347.3	348.7	350.1	351.5	352.9
25.....	354.4	355.8	357.2	358.6	360.0	361.5	362.9	364.3	365.7	367.1
26.....	368.5	370.0	371.4	372.8	374.2	375.6	377.0	378.5	379.9	381.3
27.....	382.7	384.1	385.5	387.0	388.4	389.8	391.2	392.6	394.1	395.5
28.....	396.9	398.3	399.7	401.1	402.6	404.0	405.4	406.8	408.2	409.6
29.....	411.1	412.5	413.9	415.3	416.7	418.2	419.6	421.0	422.4	423.8
30.....	425.2	426.7	428.1	429.5	430.9	432.3	433.7	435.2	436.6	438.0
31.....	439.4	440.8	442.2	443.7	445.1	446.5	447.9	449.3	450.8	452.2
32.....	453.6	455.0	456.4	457.8	459.3	460.7	462.1	463.5	464.9	466.3
33.....	467.8	469.2	470.6	472.0	473.4	474.8	476.3	477.7	479.1	480.5
34.....	481.9	483.4	484.8	486.2	487.6	489.0	490.4	491.9	493.3	494.7
35.....	496.1	497.5	498.9	500.4	501.8	503.2	504.6	506.0	507.5	508.9
36.....	510.3	511.7	513.1	514.5	516.0	517.4	518.8	520.2	521.6	523.0
37.....	524.5	525.9	527.3	528.7	530.1	531.5	533.0	534.4	535.8	537.2
38.....	538.6	540.1	541.5	542.9	544.3	545.7	547.1	548.6	550.0	551.4
39.....	552.8	554.2	555.6	557.1	558.5	559.9	561.3	562.7	564.2	565.6
40.....	567.0	568.4	569.8	571.2	572.7	574.1	575.5	576.9	578.3	579.7
41.....	581.2	582.6	584.0	585.4	586.8	588.2	589.7	591.1	592.5	593.9
42.....	595.3	596.8	598.2	599.6	601.0	602.4	603.8	605.3	606.7	608.1
43.....	609.5	610.9	612.3	613.8	615.2	616.6	618.0	619.4	620.8	622.3
44.....	623.7	625.1	626.5	627.9	629.4	630.8	632.2	633.6	635.0	636.4
45.....	637.9	639.3	640.7	642.1	643.5	644.9	646.4	647.8	649.2	650.6
46.....	652.0	653.5	654.9	656.3	657.7	659.1	660.5	662.0	663.4	664.8
47.....	669.2	667.6	669.0	670.5	671.9	673.3	674.7	676.1	677.5	679.0
48.....	680.4	681.8	683.2	684.6	686.1	687.5	688.9	690.3	691.7	693.1
49.....	694.6	696.0	697.4	698.8	700.2	701.6	703.1	704.5	705.9	707.3
50.....	708.7	710.2	711.6	713.0	714.4	715.8	717.2	718.2	720.1	721.5
51.....	722.9	724.3	725.7	727.2	728.6	730.0	731.4	732.8	734.2	735.7
52.....	737.1	738.5	739.9	741.3	742.8	744.2	745.6	747.0	748.4	749.8
53.....	751.3	752.7	754.1	755.5	756.9	758.3	759.8	761.2	762.6	764.0
54.....	765.4	766.8	768.3	769.7	771.1	772.5	773.9	775.4	776.8	778.2
55.....	779.6	781.0	782.4	783.9	785.3	786.7	788.1	789.5	790.9	792.4
56.....	793.8	795.2	796.6	798.0	799.5	800.9	802.3	803.7	805.1	806.5
57.....	809.0	809.4	810.8	812.2	813.6	815.0	816.5	817.9	819.3	820.7
58.....	822.1	823.5	825.0	826.4	827.8	829.2	830.6	832.1	833.5	834.9
59.....	836.3	837.7	839.1	840.6	842.0	843.4	844.8	846.2	847.6	849.1
60.....	849.5	851.9	853.3	854.7	856.2	857.6	859.0	860.4	861.8	863.2
61.....	864.7	866.1	867.5	868.9	870.3	871.7	873.2	874.6	876.0	877.4
62.....	878.8	880.2	881.7	883.1	884.5	885.9	887.3	888.8	890.2	891.6
63.....	892.0	894.4	895.8	897.3	898.7	900.1	901.5	902.9	904.3	905.8

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BULLETIN No. 1066

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief



Washington, D. C.



June 21, 1922

CURCULIOS THAT ATTACK THE YOUNG FRUITS
AND SHOOTS OF WALNUT AND HICKORY.

By FRED E. BROOKS,

Entomologist, Fruit Insect Investigations.

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INTRODUCTION.

Several species of snout-beetles nearly related to the common plum curculio (*Conotrachelus nenuphar* Hbst.) attack the immature fruits, tender shoots, and leaf petioles of walnut and hickory. Four such species are discussed herein, all belonging to the genus *Conotrachelus* and all having evidently at times been confused under the one most familiar species, *Conotrachelus juglandis* Lec. The four species throughout the several stages of their development resemble one another closely in appearance, habits, and seasonal activities, except that they select different food plants or have different methods of attack.

Several members of this group attack acorns and there are also several species of an allied group of snout-beetles (genus *Balaninus*) the larvæ of which feed in mature, or nearly mature, chestnuts, hickory nuts, hazelnuts, and acorns. These are not dealt with in this bulletin.

THE BUTTERNUT CURCULIO.¹

The butternut curculio has been known commonly in the past either as the "walnut weevil" or "walnut curculio." It would seem that for the members of this group whose larvæ feed in immature nuts the term "curculio" is to be preferred in order to disassociate them in the popular mind from members of the *Balaninus* group, which have long been known as "nut weevils." The other part of the name is here restricted to "butternut" for the reason that this species appears to confine its attacks almost exclusively to our native butternut (*Juglans cinerea*) and to introduced walnuts of the butternut type. There is a very similar but distinct species to which the name "walnut curculio" could be applied with equal appropriateness. In rearing several hundred specimens the writer has failed to obtain a single individual of *C. juglandis* from infested young black walnuts (*Juglans nigra*), the species commonly attacking black walnuts being *Conotrachelus retentus* Say, described on pages 7-11. One beetle of *C. retentus* was found among a lot of beetles of *C. juglandis* reared from butternuts, and it is possible that with both species of insect there is occasional interchange of hosts.

The butternut curculio also attacks and injures seriously the fruit and small branches of various species of introduced walnuts, being especially destructive to the Japanese walnuts (*J. sieboldiana* and *J. cordiformis*) which are of the butternut type. (Pl. II, *D*; Pl. III, *B*.)

DISTRIBUTION.

The known range of the butternut curculio extends from the Provinces of Ontario and Quebec, Canada, south through the New England States, Wisconsin, Iowa, and Kansas to Alabama and Georgia. Britton and Kirk² record it from 20 States within the boundary just given. The distribution of the insect follows rather closely the natural range of the butternut, which is its favorite native food plant. Throughout the general range of the insect there are evidently many localities, even where host trees abound, in which it is very rarely found. In many other localities it is abundant and destructive.

FOOD PLANTS.

Britton and Kirk² give the food plants in the order of preference shown as follows: *Juglans cordiformis*, *J. sieboldiana*, *J. cinerea*, *J. regia*, *J. nigra*, and *J. mandshurica*. They quote Dr. Robert T. Mor-

¹ *Conotrachelus juglandis* Lec.; suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

² BRITTON, W. E., and KIRK, H. B. LIFE HISTORY AND HABITS OF THE WALNUT WEEVIL OR CURCULIO. In 12th Ann. Rept. State Ent. Conn., p. 240-253. 1912.

ris, a nut grower, of New York City and Stamford, Conn., as stating that he has observed this curculio on various species of hickory. Blatchley and Leng³ record the species as "occurring on walnut, butternut, and hickory, the larvæ breeding in the green fruit."

The present writer has found this curculio attacking extensively the fruit of our native butternut (*J. cinerea*) and the shoots and leaf petioles of the Japanese walnuts (*J. sieboldiana* and *J. cordiformis*). It was found less frequently feeding and ovipositing in the shoots of the native butternut and the fruits of the Japanese walnuts. Several beetles were found in September on the branches of a young tree of *Juglans cathayensis* growing in Arnold Arboretum, at Boston, Mass., and there were evidences of serious injury to the branches made earlier in the season by the larvæ. Similar although less extensive injury was noted on a tree of the same species growing in one of the parks of Rochester, N. Y.

NATURE AND EXTENT OF INJURY.

The injury inflicted by this insect consists of feeding punctures made by the adults in the nuts, tender tips, and leaf petioles and the burrows of the larvæ in the nuts and new growth of various species of walnuts. Extensive injury has been reported from Connecticut,⁴ where young transplanted trees and trees in the nursery row have been partially or entirely killed by the larvæ working in the branches. The most serious loss of this kind has been to the Japanese walnuts, although trees of the Persian walnut have suffered to some extent. Britton and Kirk⁵ describe infestation in one nursery as follows:

In a nursery at New Canaan [Conn.], about the middle of September, Mr. Kirk noticed a row containing about 265 trees of *Juglans sieboldiana* on all of which the larvæ were tunneling in the new growth. An adjoining row of about the same number of *J. regia* trees was only slightly attacked, and another adjoining row containing about 400 trees of black walnut, *J. nigra*, were uninfested. Several hundred other trees of *J. sieboldiana* in another part of the same nursery were badly infested, not a single tree escaping. Here, also, was noticed the fall attack of the adults at the base of the leaf petioles, and two adults were collected.

During the present investigation the writer has observed serious injury to young trees of *J. sieboldiana*, *J. cordiformis*, and *J. cathayensis* in Massachusetts, Connecticut, and New York. Southward, particularly in Maryland and West Virginia, extensive attacks upon the fruit of the native butternut occur regularly. Many cases have been observed in which 50 per cent or more of the nuts dropped from trees prematurely on account of injury by the curculio larvæ, the percentage of loss being greatest in years of light crops. Farther

³ BLATCHLEY, W. S., and LENG, C. W. RHYNCHOPHORA OR WEEVILS OF NORTHEASTERN AMERICA, p. 469. 1916.

⁴ BRITTON, W. E., and KIRK, H. B. Op. cit.

north attacks upon the fruit of the native butternut seem less extensive, although at least a few infested nuts can usually be found upon or beneath any bearing tree. A case of slight injury to the nuts was found in 1920 in Jefferson County, N. Y. At nearly the same time about 20 bearing butternut trees were examined along the St. Lawrence River, in St. Lawrence County, N. Y., and not a trace of the insect found. Beetles were reared from both shoots and fruit of *J. sieboldiana* collected at Lockport, N. Y., and larvæ were abundant in butternuts collected at Lake Winnepesaukee, in central New Hampshire.

Occasionally the larvæ are found boring in young shoots of butternut at French Creek, W. Va., oviposition evidently taking place in the tips of these shoots before the fruit is large enough to be attacked. On July 2, 1920, in the last-named locality, 60 half-grown butternuts were picked at random from the lower branches of one tree. Of these 60 nuts 48 contained egg punctures of the curculio and 12 were sound. A number of nearly full-grown larvæ were also found boring in the terminal shoots and leaf petioles. These larvæ averaged larger than those in the nuts, indicating, as in numerous other observations made, that eggs are first laid in the shoots.

LIFE HISTORY.

The butternut curculio has but one generation annually, and, like other members of the genus, passes the winter in the adult stage. In West Virginia oviposition begins in May and continues practically all summer, apparently reaching its maximum the last of June or the first of July.

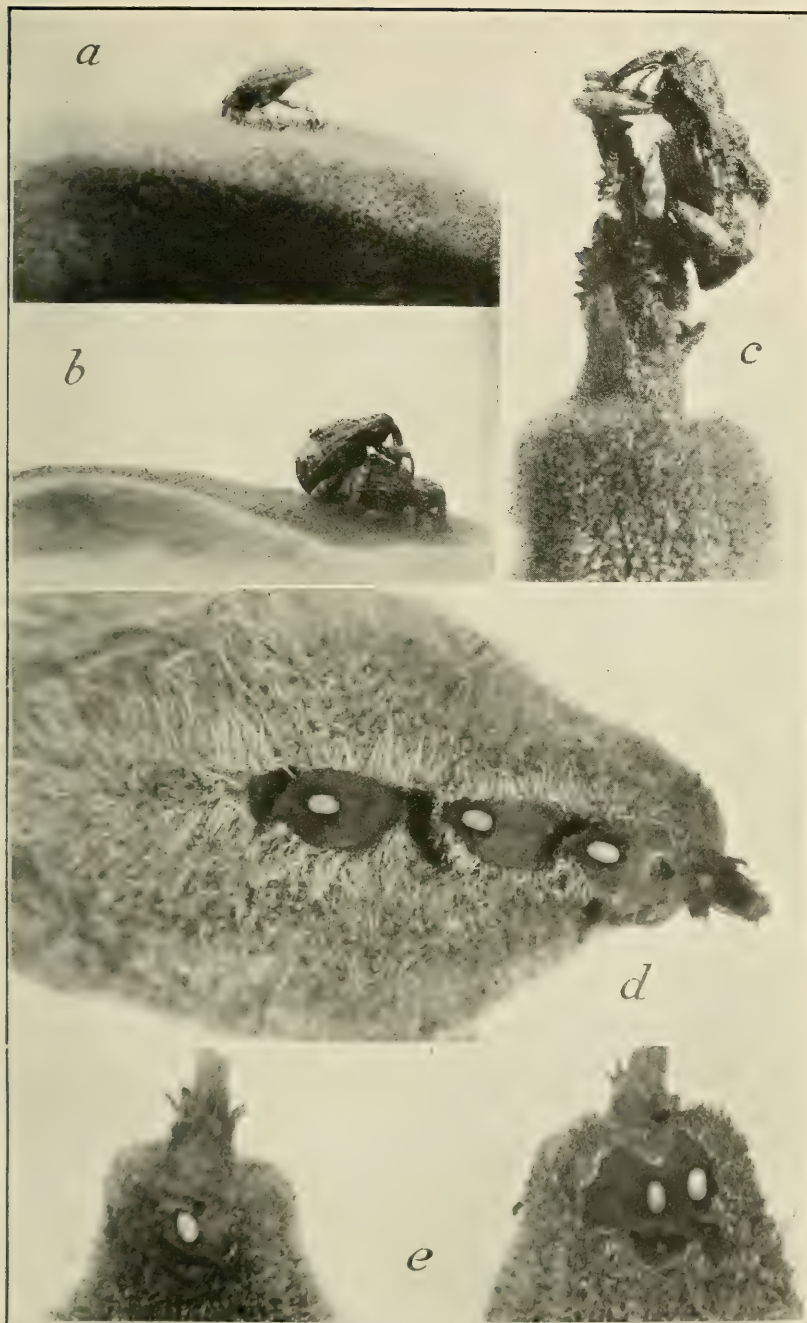
EGG.

The egg is oblong, oval, creamy white, with the surface like ground glass. (Pl. I, *D* and *E*; Pl. II, *A*, *B*, and *C*.) Three measured on July 2, 1920, were uniformly 1 mm. long by 0.6 mm. wide. Two measured on June 7, of the same year, were 0.9 mm. long by 0.6 mm. wide. Britton and Kirk⁵ give the following dimensions: Length, 0.95 mm.; thickness, 0.57 mm. Most of the eggs hatch in from 8 to 10 days, although the period may extend to 15 days.

LARVA.

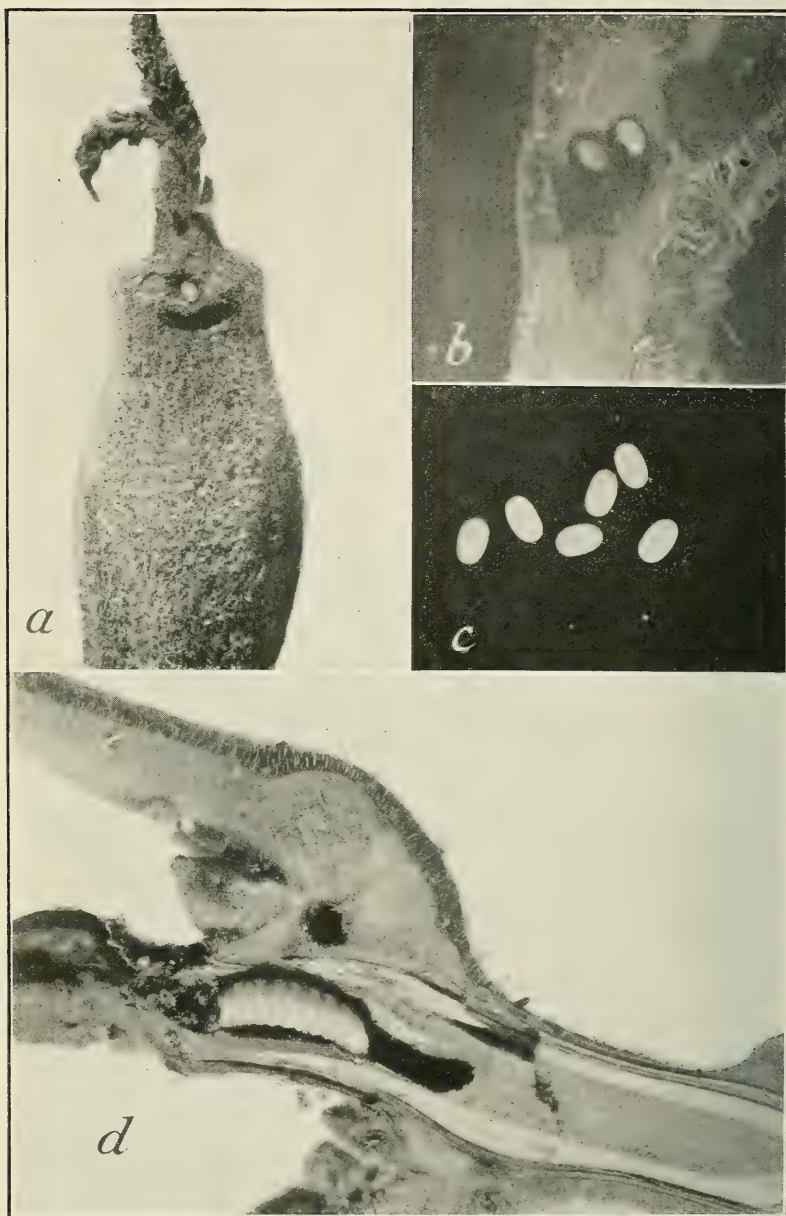
The larvæ are whitish, or dirty white, with brown head and blackish mandibles. (Pl. II, *D*; Pl. III, *A* and *B*.) The length is 12 to 13 mm. and the thickness 3 mm. Feeding in the nuts and shoots, they become full grown in four or five weeks and then enter the ground to pupate. Nuts that are attacked when very small usually furnish

⁵ BRITTON, W. E., and KIRK, H. B. Op. cit.



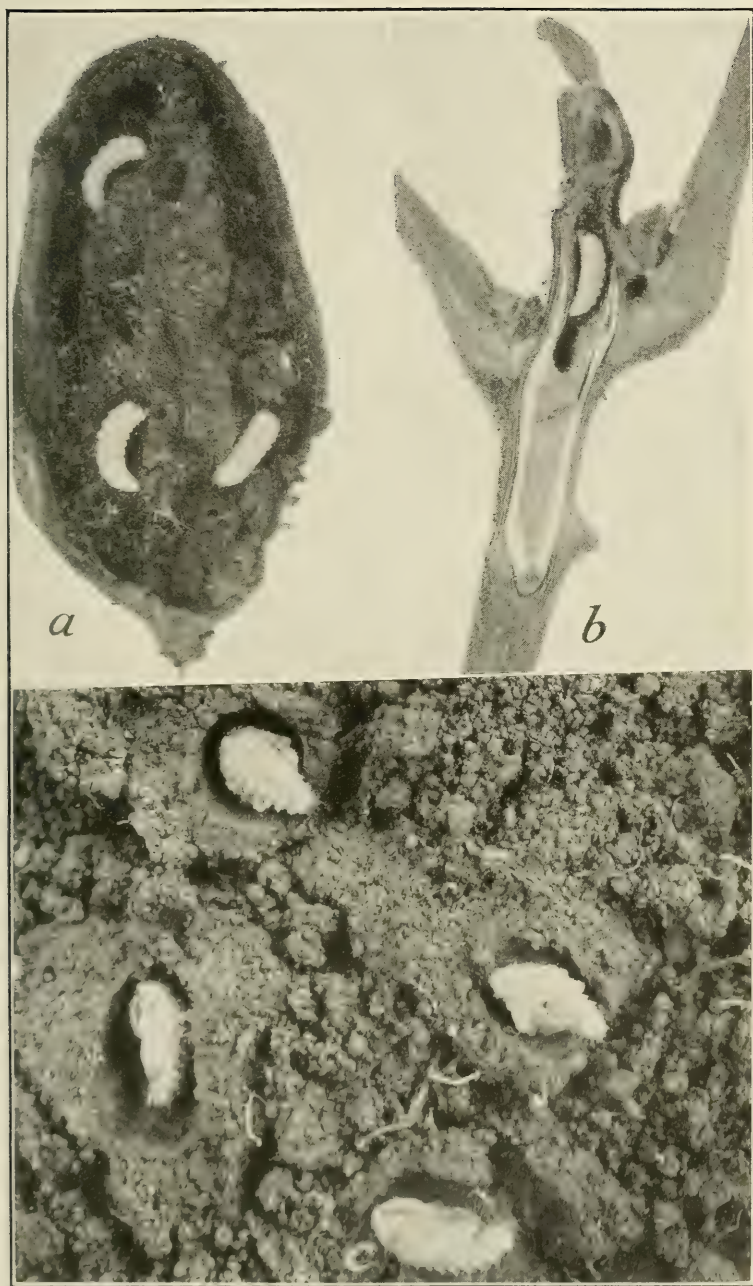
THE BUTTERNUT CURCULIO.

a, Adult curculio excavating egg chamber in butternut; *b*, adult female excavating egg chamber accompanied by male; *c*, curculio on tip of young butternut, a favorite resting place; *d*, eggs in young butternut exposed by cutting away the skin; *e*, eggs near tip of butternuts, a favorite place for oviposition while the nuts are small. All enlarged.



THE BUTTERNUT CURCULIO.

a, Egg and egg-punctures near tip of young butternut, egg exposed by removing skin of nut;
b, eggs in shoot of Japanese walnut; *c*, eggs; *d*, larva boring in pith of Japanese walnut shoot.
All enlarged.



THE BUTTERNUT CURCULIO.

a, Larvæ in husk of butternut; *b*, larva in shoot of Japanese walnut; *c*, pupæ within pupal cells in the ground. All slightly enlarge 1.

enough food to bring only one larva to maturity, but nuts that become infested when larger may contain from four to six larvæ which reach full growth. After leaving their feeding places preparatory to pupation the larvæ are active and crawl rapidly. When exposed to the light they have a habit of bending and catching the anal tip under the jaws and then releasing the tip with a jerk, sometimes throwing themselves in this way a distance equal to the length of the body. The larvæ issue chiefly in the early morning hours and enter the soil as quickly thereafter as possible. In West Virginia larvæ began to issue from butternuts on July 18 and continued to appear until September 4. Table 1 shows the rate of emergence.

TABLE 1.—*Time and rate of emergence of larvæ of the butternut curculio from half a bushel of butternuts at French Creek, W. Va., during the season of 1920.*

Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.
July 18.....	3	Aug. 5.....	4	Aug. 23.....	9
19.....	0	6.....	2	24.....	3
20.....	16	7.....	5	25.....	1
21.....	0	8.....	1	26.....	1
22.....	9	9.....	8	27.....	0
23.....	1	10.....	4	28.....	0
24.....	5	11.....	5	29.....	0
25.....	11	12.....	2	30.....	0
26.....	153	13.....	2	31.....	0
27.....	22	14.....	7	Sept. 1.....	0
28.....	10	15.....	2	2.....	3
29.....	2	16.....	0	3.....	0
30.....	1	17.....	0	4.....	4
31.....	0	18.....	4	5.....	0
Aug. 1.....	13	19.....	1		
2.....	97	20.....	0	Total.....	464
3.....	40	21.....	1		
4.....	1	22.....	9		

As set forth in Table 1, 464 larvæ issued from half a bushel of infested butternuts over a period of 49 days. It is an interesting fact that emergence was much more rapid during cool than warm weather. For example, on the mornings of July 26 and August 2, the dates of maximum emergence of the larvæ, the temperature registered, respectively, 46° and 54° F. More than half the entire number of larvæ issued on these two mornings of unusual cold.

PUPA.

The pupa (Pl. III, C) is creamy white, the color deepening and the eyes becoming dark as the adult stage is approached. The length averages 10 mm. and the thickness 5 mm. The entire ventral surface is sparsely covered with short, stiff hairs. The pupa occupies a smooth-walled cell from 1 to 3 inches below the surface of the ground. Nearly a month is spent beneath the ground by the insect in the pre-pupa, pupa, and young adult stages and then it emerges as a fully developed beetle and seeks the branches of a host tree.

ADULT.

The beetle (Pl. I, *A*, *B*, and *C*) resembles very closely the common plum curculio, being brownish gray with a variable, whitish, curved line on each side of the thorax and a broad whitish band behind the middle of the elytra. The back is marked with prominent humps and ridges and is covered with short gray and whitish pubescence. The strong curved beak is nearly half as long as the body, and the body, exclusive of the beak, averages about 7 mm. in length. The general appearance of the beetle is rough and angular.

The young beetles issue from the soil in late summer and early autumn, 64 individuals issuing in West Virginia between August 17 and September 6. Of these beetles the maximum daily emergence of 13 took place on August 27. A few beetles continued to come from earth in rearing jars up to the middle of October. These young beetles reach the trees before those of the parent generation have all died, and, like them, feed sufficiently in the autumn on the surface of terminal shoots and leaf petioles to suggest their destruction with arsenical sprays in September or early October. The beetles go into hibernation, probably in litter on the ground, with the approach of freezing weather.

The beetles issue from hibernation in the spring at about the time walnut trees come into bloom and resort at once to their host trees. They may at this time be jarred in abundance from butternut trees, a few having been taken in West Virginia by jarring black walnut and hickory trees growing near butternut trees. With very few exceptions, however, the species jarred from black walnut at this season of the year has been *C. retentus* and those from hickory *C. aratus*. This usually holds good even where the three kinds of trees grow in close proximity.

Feeding begins in a limited way soon after the beetles appear on the trees, the food consisting of stem and leaf tissues of the new growth. The feeding marks in the stems are in the form of irregular pits reaching through the bark and are sometimes extensive enough to cause the leaves and tips to droop and die. Oviposition soon begins, the first eggs being laid in the new growth which forms before the fruit is large enough to be attacked. In the native butternut most of the eggs are withheld until the nuts are large enough to receive them, this being when the nuts are about an inch long. In young and tender nuts practically all the eggs are placed in crescent-shaped marks eaten into the husk near the blossom end. (Pl. I, *E*; Pl. II, *A*.) By means of an extrusive ovipositor the egg is thrust into a small pocket excavated beneath the tongue of skin on the concave side of the crescent. The beetles are often found resting upon the remnants of the blossom that project from the tip of the young

nuts (Pl. I, C), and in excavating the egg chamber in such nuts the female beetle takes her position on this withered part of the blossom, and, with her head pointing toward the nut, proceeds to excavate the crescent-shaped egg chamber. On account of her method of work the concave side of the crescent faces the tip. (Pl. II, A.) It is not unusual to find a young butternut with a row of these crescent marks completely encircling the blossom end.

As the nuts develop and the husk becomes tougher the beetle changes somewhat her method of procedure, and instead of cutting out the crescents for her eggs, places them in simple cavities gouged into the side of the nut through small openings in the skin. Such cavities are usually arranged in groups, the skin about the wounds being marked by dark stains from slight exudations of juice and from excrement voided by the beetle during the excavating process. These groups of punctures often contain half a dozen eggs each, one having been found by the writer which contained 11.

NATURAL ENEMIES.

During this investigation two species of dipterous parasites have been reared in West Virginia from larvæ of the butternut curculio. These have been determined by Dr. J. M. Aldrich, of the United States National Museum, as *Chaetochlorops inquilina* Coq. and *Cholomyia longipes* Fab. Both species are rather abundant, the first-named, especially, rendering good service in holding the curculio in check. Other investigators have reared the following species from this host: *Metadexia basalis* G.-T., *Cholomyia inaequipes* Bigot, *Myiophasia aenea* Wied., and *Sigalphus curculionis* Fitch.

THE BLACK-WALNUT CURCULIO.*

In June, 1919, the ground beneath bearing black walnut trees (*Juglans nigra*) at French Creek, W. Va., was found to be strewn thickly with young nuts the size of small marbles. Examination showed that each nut contained a single dirty-white larva half an inch or less in length. A quantity of the nuts were collected and placed in rearing jars with the expectation that in due time beetles of *Conotrachelus juglandis* would be reared therefrom. When the beetles appeared, however, they were slightly different from *C. juglandis*, and specimens submitted to Mr. E. A. Schwarz, of the United States Department of Agriculture, were determined as *Conotrachelus retentus* Say, a species the habits of which had hitherto been practically unknown. Further observations proved that this species attacks commonly the young fruits of black walnut in many localities in the eastern part of this country.

* *Conotrachelus retentus* Say; suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

DISTRIBUTION.

This species was described and named nearly a century ago by Thomas Say.⁷ Since Say's description was published entomologists have from time to time collected specimens of the beetle, but no data on the feeding habits of the species have found their way into print. There are records of beetles being collected at Allegheny, Pa., Topeka, Kans., Mendenhall, Miss., and Haulover, Fla. During the present investigation the writer has collected the species at Harrisburg and York, Pa.; Hagerstown, Cumberland, and New Windsor, Md.; Morgantown and French Creek, W. Va.; Fincastle, Gala, Lick Run, Marion, McDowell, Oak Ridge, Pulaski, and Radford, Va.; and Black Mountain and Hickory, N. C.

FOOD PLANTS.

No food plants of this curculio seem to be known other than the black walnut (*Juglans nigra*) and butternut (*J. cinerea*). Of these two, the black walnut is much preferred, only one beetle of the species having been obtained in extensive rearings from butternut. Hamilton records taking the beetles by beating red oak sprouts, and the present writer has collected them from hickory trees growing close to black walnut. The occurrence of the beetles on both the red oak and hickory was probably accidental.

NATURE AND EXTENT OF INJURY.

Except for its different food plant, this species corresponds very closely in all its activities as well as in appearance with the butternut curculio. The adults feed on the tender shoots and leaf petioles and make oviposition scars and feeding punctures in young black walnuts similar to those made in butternuts by the other species. The larvæ develop in young black walnuts and cause the nuts to drop, usually before they are half grown. The larvæ are occasionally, but rarely, found burrowing in the tender shoots of black walnut.

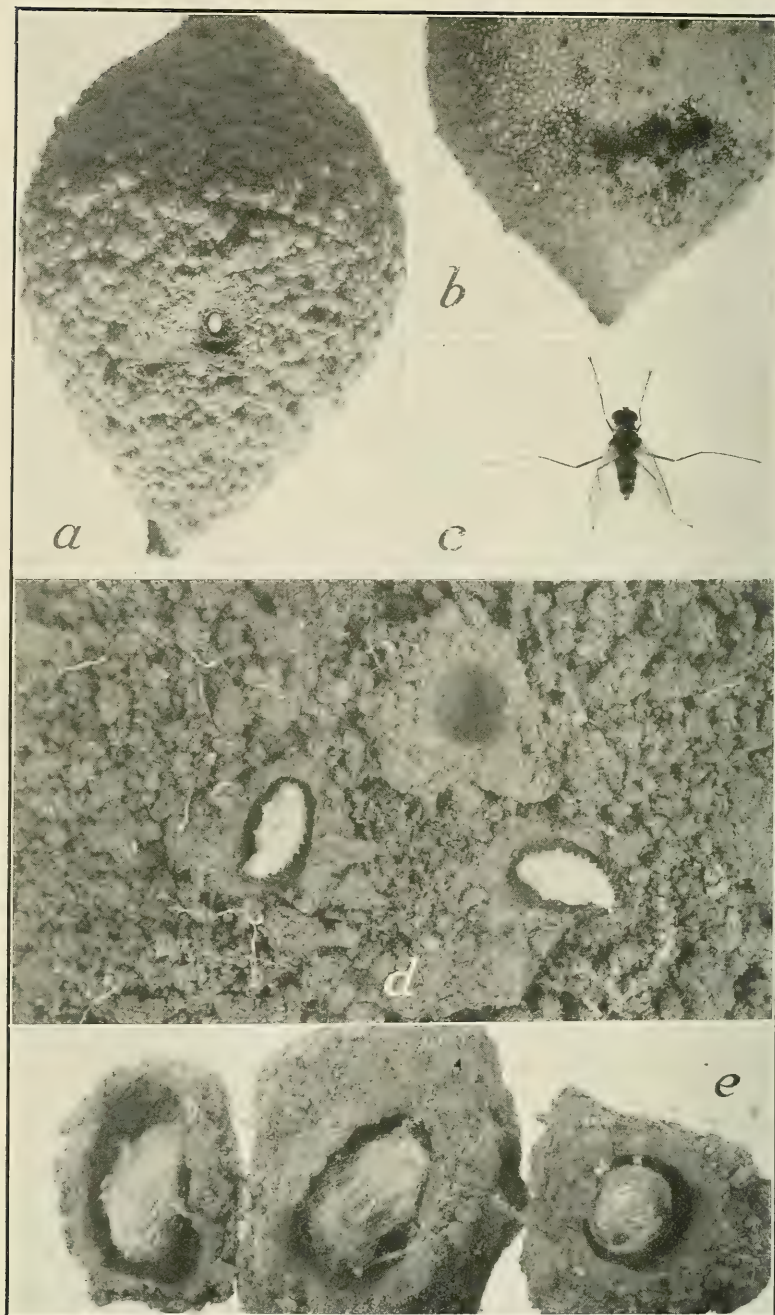
In seasons when black walnut trees are bearing a light crop of nuts a large percentage of the crop may become infested and drop, but in years of heavy fruitage the curculios do no more than to effect an unimportant thinning of the nuts. The following notes of field observations indicate degrees of infestation such as were frequently noted. On June 15, 1920, 17 newly set black walnuts were picked from the lower branches of a tree growing in a parklike woods near Cumberland, Md. Of these 17 nuts, 16 contained curculio egg punctures and the other a feeding puncture. On the 16th of the same month 50 per cent of the nuts on trees growing along the highway at New Windsor, Md., were found infested. At French

⁷ SAY, THOMAS. ENTOMOLOGY OF NORTH AMERICA. (Leconte ed.) v. 1, p. 295. 1859.



THE BLACK-WALNUT CURCULIO.

a and *d*, Female beetles excavating egg chamber in young black walnuts; *b*, egg; *c*, larva constructing pupal cell in the ground; *e*, egg punctures in young walnut; *f*, pupa; *g*, egg punctures in walnuts.



THE BLACK-WALNUT CURCULIO.

a, Egg in natural position exposed by removing skin of young black walnut; *b*, group of egg punctures in half-grown black walnut; *c*, parasitic fly *Cholomyia longipes*; *d*, pupæ within pupal cells in earth; *e*, cocoons of the parasite *Thersilochus conotracheli* occupying the pupal cells of the curculio after killing and devouring the host larvæ. All enlarged.

Creek, W. Va., 400 young nuts were gathered at random from the lower branches of four black walnut trees growing in a pasture field. Of this lot of nuts 289 contained 466 egg punctures and the remaining 111 were sound. In another instance in the locality last mentioned 1,447 infested nuts dropped from one tree during the season.

So far as observations have been made, the black walnut curculio seems much more abundant and injurious in the latitude of Maryland and West Virginia than within the range of the black walnut farther to the north. In the vicinities of Trenton, N. J., Lancaster, Pa., Rochester and Lockport, N. Y., and Wallingford, Conn., a number of bearing black walnut trees were examined without finding any evidences of the presence of the curculio. Locality records by various entomologists and observations made during the present investigation indicate a southern rather than a northern range for this species.

LIFE HISTORY.

EGG.

The egg (Pl. IV, *B*; Pl. V, *A*) is oval, oblong, creamy white, surface delicately granulose, 1 mm. long by 0.7 mm. wide. Eggs that are deposited in young, tender nuts are placed beneath the flap of skin within a crescent-shaped puncture eaten out of the side of the nut (Pl. IV, *E*, *G*). In the more solid husk of half-grown nuts the eggs are inserted in less elaborate punctures which resemble pin pricks and extend directly into the husk. (Pl. V, *B*.) These simple egg punctures in the more nearly mature nuts are usually formed in groups of from three to six on the side of the nut.

About a dozen eggs deposited in nuts on the trees on July 15 hatched on the morning of July 22 and an equal number deposited on July 16 hatched on July 23, an incubation period in both cases of 7 days under natural conditions. Two other lots of eggs laid and kept in an open insectary hatched in five and six days, respectively. In West Virginia oviposition begins normally during the last days of May and continues through June and most of July.

LARVA.

The larva (Pl. IV, *C*) is creamy white with brown head, legless, and fusiform. It assumes naturally a curved position and is sparsely clothed with short, stiff hairs. The length is 11 mm. and the thickness 3 mm. As soon as hatched it begins to feed from the side of the oviposition wound, and, in young nuts, soon devours the whole interior. In the older nuts feeding is done chiefly in the husk. The infested nut adheres to the branch until the larva is at least half grown, and then drops, the larva continuing to feed while the nut

dries and hardens on the ground. When the larva is full grown it ceases feeding, assumes a clearer cream color, and, after a period of a week or two of inactivity within the nut, cuts its way out through the shell and enters the ground to a depth of from 2 to 4 inches to pupate. Larvæ may be found in the nuts from early in June until late in September. In one lot of 805 larvæ which issued from infested black walnuts kept in rearing jars the first larva left the nut on July 14 and the last on September 21. These larvæ, like those of the butternut curculio, chiefly issued early in the morning and the largest numbers always in cool weather. In small green nuts only one larva matures to the nut, but two or three larvæ may develop together in a large nut. Apparently where several larvæ hatch and begin feeding in a small nut one individual always kills and devours the others. In two or three instances one larva was found killing and eating its fellow. On entering the ground the larva seeks a place where the soil is solid and fashions a smooth-walled cell (Pl. IV, *C*; Pl. V, *D*), where it rests for several days before pupating.

PUPA.

The pupa (Pl. IV, *F*; Pl. V, *D*) is white and is about 9 mm. long by 3 mm. thick. The abdomen, thorax, and wing pads are covered thinly with short, stiff hairs, these hairs being shortest on the wing pads. The pupa occupies an unlined earthen cell from 2 to 4 inches beneath the surface of the ground. The pupa stage covers a period of from two to three weeks.

ADULT.

The mature beetle (Pl. IV, *A* and *B*) is dull reddish-brown and covered with grayish pubescence. There is a lighter colored, indistinct, broad band behind the middle of the elytra and a vague, broken line of the same lighter shade on each side of the thorax. The snout is half as long as the body and the back is ridged and punctured. The length averages from 6 to 7 mm. This beetle in size and general shape resembles very closely the butternut curculio but its color markings and elytral sculpturing are less pronounced.

The newly developed beetles begin issuing from the ground in August; the first specimens were obtained in this investigation on August 7. In one rearing cage 75 beetles came from the ground between August 13 and September 2, the maximum emergence taking place from August 24 to 29.

In late summer and early autumn the young beetles may be found on their host trees, where they apparently feed on the leaf petioles before seeking their hibernation quarters. The beetles live through the winter, probably hidden in the duff at the surface of the ground,

and resume activity in the spring in time to be on black walnut trees when the male catkins of the walnut are fully developed. As soon as the leaves and tender shoots appear the beetles attack them, sometimes feeding rather extensively. Soon thereafter they begin egg-laying in the young fruit. There is considerable variation in the time the fruit sets on individual trees of the black walnut in any locality and the beetles collect on the trees where the developing nutlets are at the stage just to their liking. This is immediately after the female catkins on the point of the nut are beginning to wither. Most of the eggs are deposited in nuts at this stage of their development, although the beetles continue to oviposit to some extent in nuts that are larger.

The beetles live normally throughout most of the summer and oviposit over a period of at least two months. Several overwintering beetles confined in screen cages placed over walnut branches on the trees lived until the last of August. It is thus possible in late summer to find the parent beetles and their mature offspring together on the trees.

NATURAL ENEMIES.

At least five species of insect parasites were found attacking the black walnut curculio in its larva and pupa stages. Three species of parasitic flies, determined by Dr. J. M. Aldrich as *Chaetochlorops inquilina* Coq., *Cholomyia longipes* Fab. (Pl. V, C), and *Fannia canicularis* L., were reared from this host in considerable numbers. Two hymenopterous parasites, determined by Mr. R. A. Cushman as *Trispis curculionis* var. *rufus* (Riley) and *Thersilochus conotracheli* (Riley) (Pl. V, E) were also obtained in the rearing jars. Still another parasite, determined by Mr. R. A. Fouts as a new species of *Belyta*, was found in jars in which this curculio was being reared.

THE HICKORY-NUT CURCULIO.⁸

The hickory-nut curculio is very similar to the two species just discussed, but it attacks the immature nuts of various kinds of hickory instead of walnuts. The beetles appear upon the trees somewhat later in spring than the other two and lay their first eggs in hickory nuts that are at least half grown, although before the nut kernels have begun to form. The most conspicuous manifestation of the presence of the insect is the dropping of the infested nuts about midsummer. It is not unusual in July and August to find in some localities the ground beneath bearing hickory trees strewn thickly with green nuts. Examination of these nuts will disclose a brownish oviposition scar

⁸ *Conotrachelus affinis* Boh.; suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

on the side of the nut (Pl. VI, *C*) and a whitish larva feeding within. (Pl. VI, *D*.) The dropping of nuts from this cause is sometimes very heavy.

HISTORY AND DISTRIBUTION.

This species was described and named in 1837 by Boheman.⁹ Since the original description was published the species has been referred to occasionally by entomologists, but it has at no time attracted extensive notice. It has been recorded from the States of New Jersey, Ohio, Virginia, West Virginia, Louisiana, Florida, and the District of Columbia.

FOOD PLANTS.

During the last 15 years the writer has reared this curculio frequently from hickory nuts in West Virginia. Pierce¹⁰ has reared it from hickory nuts in Louisiana. Apparently its attacks are confined to the nuts of various species of hickory. In West Virginia the nuts of the pignut hickory, *Hicoria glabra*, seem to be preferred to those of other species, although shagbark hickory nuts, *H. ovata*, are sometimes attacked extensively. Nuts of *H. alba* and *H. minima* are attacked to some extent and it is probable that injury may occur to the nuts of all species of hickory that grow within the range of the insect.

LIFE HISTORY.

EGG.

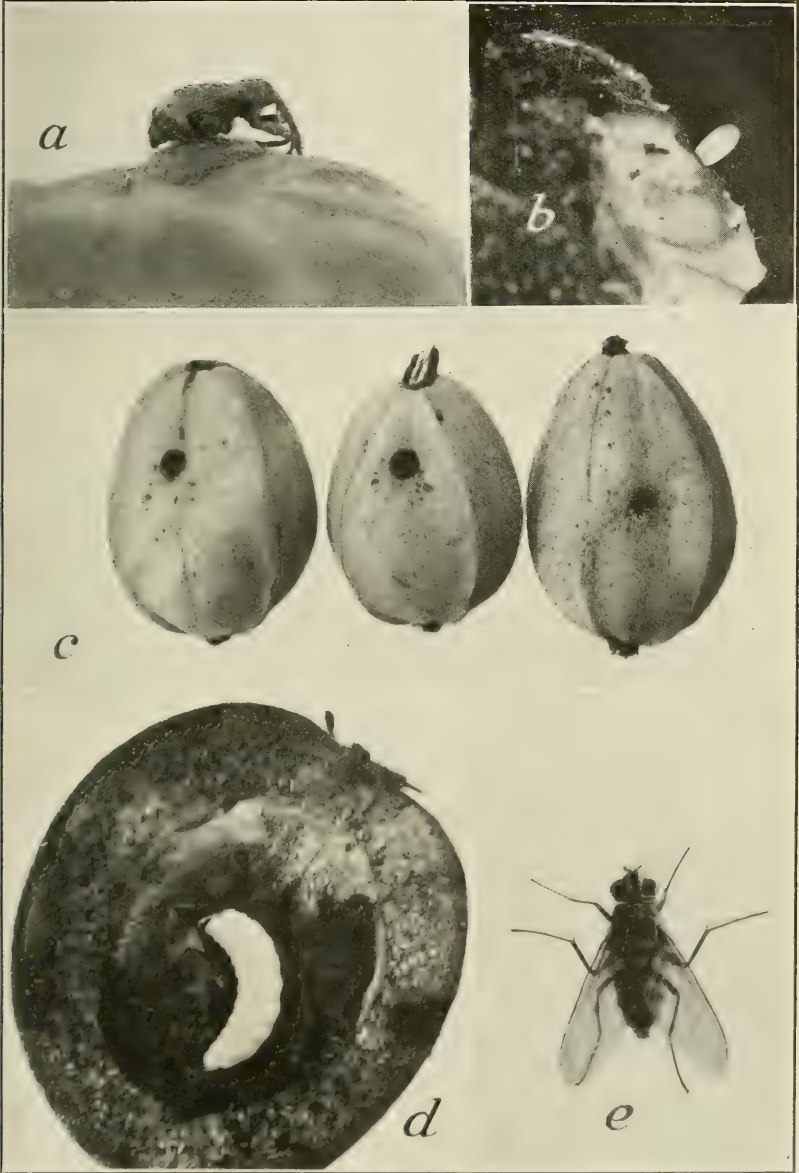
The egg (Pl. VI, *B*) is oblong, elliptical, translucent white, the surface smooth and shiny. The average dimensions are 1 mm. long by 0.6 mm. thick. The eggs hatch in from five to seven days.

LARVA.

The larva (Pl. VI, *D*) is white with light brown head, full-grown specimens measuring 12 mm. in length. The larvæ are practically identical with those of the preceding species except that they taper somewhat more abruptly at the anal end than *Conotrachelus retentus*, and the bristles, with which the body is sparsely clothed, are shorter and less conspicuous than in *C. juglandis*. They are found feeding singly in fallen nuts during the months of July and August. The infested nuts drop about 20 days after oviposition takes place, or about 2 weeks after the larvæ begin to feed. At the time of dropping, the nuts average from one-half to two-thirds grown.

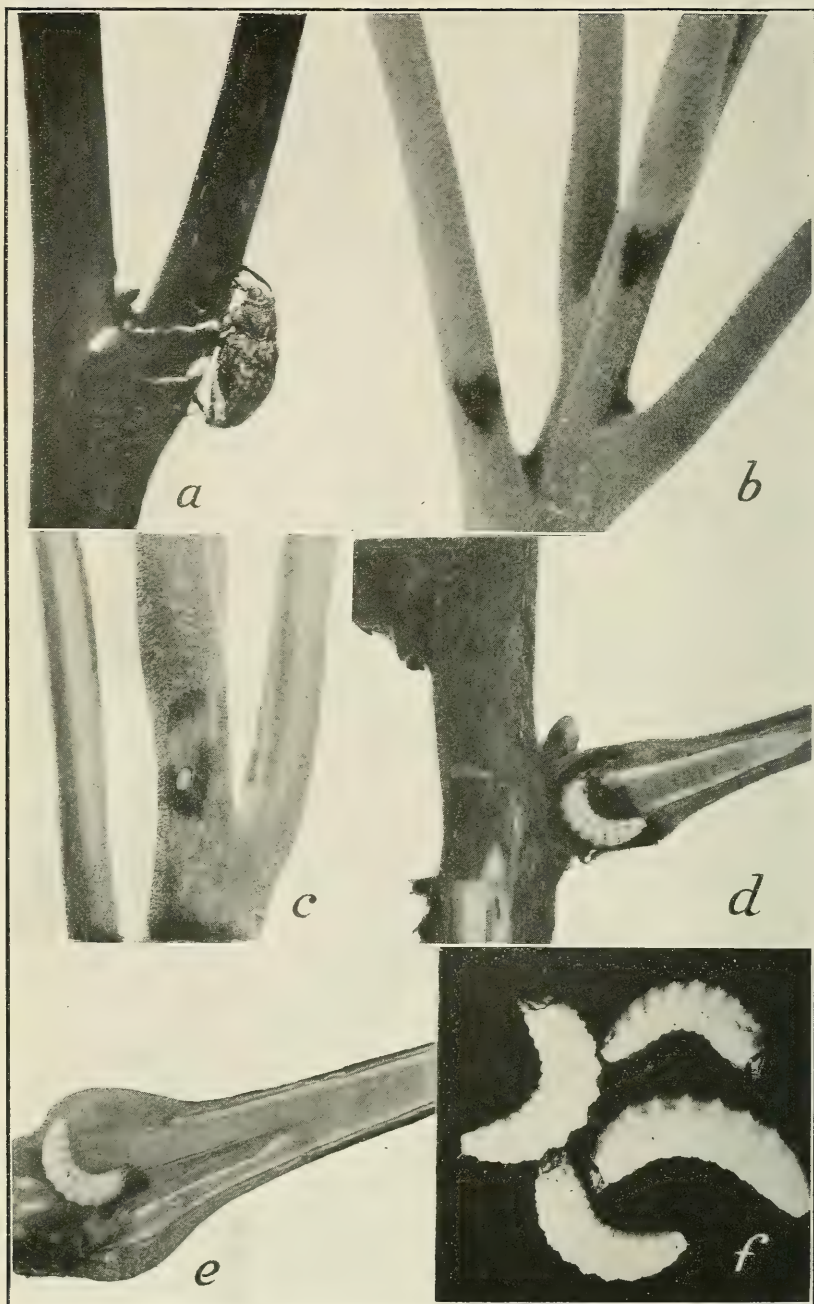
⁹ BOHEMAN, C. H., In SCHOENHERR, C. J. SYNONYMIA INSECTORUM. GENERA ET SPECIES CURCULIONIDUM, t. 4, pars. 1, p. 429-430. 1837.

¹⁰ PIERCE, W. DWIGHT. ON THE BIOLOGIES OF THE RHYNCHOPHORA OF NORTH AMERICA. Studies from the Zoological Laboratory of the University of Nebraska, No. 78. Nebr. State Bd. Agr., Rpt. Zoologist, p. 274. 1907.



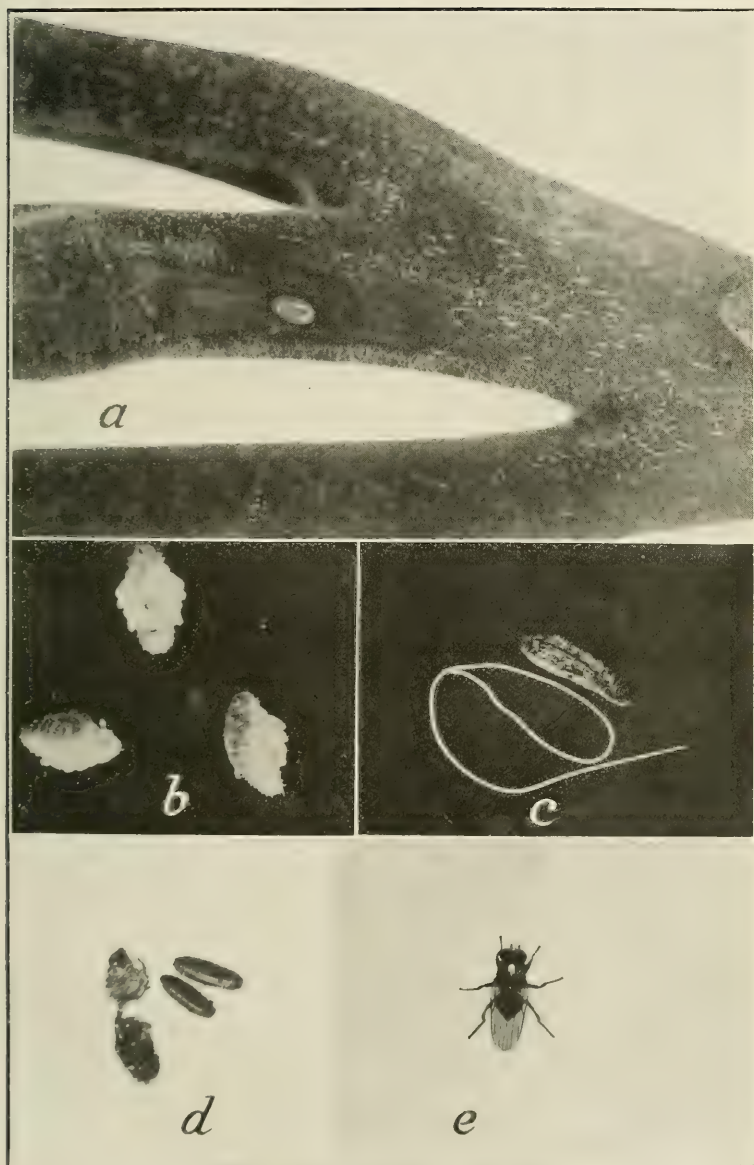
THE HICKORY-NUT CURCULIO.

a, Adult curculio resting on hickory nut; b, egg exposed by cutting away the husk of the nut from around the egg chamber; c, oviposition scars in shagbark hickory nuts; d, larva feeding in shagbark hickory nut; e, parasitic fly *Chotomyia longipes*.



THE HICKORY-SHOOT CURCULIO.

a, Adult excavating egg chamber in leaf petiole; *b*, oviposition scars; *c*, egg exposed by cutting away bark; *d* and *e*, larvæ feeding at base of leaf petioles; *f*, larvæ



THE HICKORY-SHOOT CURCULIO.

a, Egg in hickory shoot, exposed by removing bark; *b*, pupæ; *c*, hairworm parasite of larva by dead body of its host; *d*, curculio larva killed by larvae of parasitic fly, *Chactochlorops inquilina*, with pupæ of parasite on right; *e*, adult parasite *C. inquilina*.

The larvæ continue feeding in the nuts for 10 days or 2 weeks after they are on the ground and then leave through exit holes made at the oviposition scar.

PUPA.

The pupa is delicate white, sparsely covered with short bristles, as in *juglandis* and *retentus*, and is of the same general size and shape as the adult. Pupation usually takes place within unlined cells of earth an inch or two below the surface of the ground. In a few instances pupation was found occurring within host nuts that were buried beneath damp, fallen leaves. The pupa stage covers a period of approximately 30 days.

ADULT.

The adult (Pl. VI, *A*) is reddish brown with a conspicuous broad band of a lighter grayish shade behind the middle of the elytra. The snout is long, and the general size, shape, and markings of the beetle are similar to those of *C. juglandis* and *C. retentus*. It may be distinguished from *C. retentus* by its more reddish color, the light markings on the thorax and elytra often having a pinkish cast, and from *C. juglandis* by the less prominent humps and ridges of the elytra and also by the more pronounced reddish shade of the elytral and thoracic bands and markings.

The young beetles issue from the ground from August to October; they have appeared in rearing jars at French Creek, W. Va., from August 12 to October 15. Soon after emergence from their pupal quarters they go into hibernation and do not reappear until late the following spring.

Oviposition in the latitude of West Virginia begins late in June and covers a period of at least four weeks. The eggs are laid in circular or sometimes crescent-shaped scars on the side of the nut, the scars soon taking on a brownish or blackish color and becoming rather conspicuous. (Pl. VI, *C*.) It has been observed frequently that in nuts of *Hicoria glabra* the oviposition marks are made near the point of the nut, while in those of *H. ovata* the marks are directly on the side or near the stem end. Also, beetles developing from nuts of *H. ovata* average larger than those from the nuts of *H. glabra*.

The beetles are especially active at nightfall and have been observed ovipositing after dark.

NATURAL ENEMIES.

Numerous specimens of a parasitic fly were reared in September from larvæ of this curculio. (Pl. VI, *E*.) The species was determined by Dr. J. M. Aldrich as *Cholomyia longipes* Fab. A few specimens of another fly determined by Aldrich as *Myiophasia globosa* Towns. were also reared from the larvæ. Two hymenopterous species were

found parasitic upon the larvæ; one of these was determined by Mr. R. A. Cushman as *Triaspis curculionis* var. *rufus* (Riley) and the other by Mr. C. F. W. Muesebeck as a new species of *Microgaster*. Pierce¹¹ records rearing the parasitic fly *Myiophasia aenea* Wied. from this host.

THE HICKORY-SHOOT CURCULIO.¹²

Soon after the growth of hickory begins in the spring the tender tips and leaf petioles may be found disfigured by dark, V-shaped marks on the bark about an eighth of an inch long. (Pl. VII, *B*.) These are the egg punctures of a small snout-beetle which may be known as the hickory-shoot curculio. Often these marks occur in series of from 5 to 10 along the shoot, one above each leaf axil. Examination of these marks usually discloses either the single white egg (Pl. VII, *C*; Pl. VIII, *A*) or a small white grub feeding in the stem (Pl. VII, *D* and *E*). The affected tip or leaf usually withers and drops as a result of the injury. No instance of serious loss from this insect has come under the writer's notice, but injurious attacks, especially to newly transplanted hickory trees, are a possibility.

DISTRIBUTION.

This species was described from Kentucky in 1824 and has since been recorded from Massachusetts, Connecticut, New Jersey, Florida, and Texas. The writer has found it abundantly at French Creek, W. Va., and has observed its work in other West Virginia localities.

FOOD PLANTS.

This curculio has been observed attacking the shoots of the following hickories in West Virginia: *Hicoria minima*, *H. ovata*, *H. alba*, *H. glabra*, and *H. pecan*.

LIFE HISTORY.

EGG.

The egg (Pl. VII, *C*; Pl. VIII, *A*) is oval, oblong, creamy white, semitransparent, and averages 1.1 mm. by 0.7 mm. It occupies a shallow cavity at the side of an elongate slit which the female beetle makes with her snout in the bark of tender twigs and leaf petioles. (Pl. VII, *A*.) After the egg is deposited the bark over the egg cavity and along the edges of the slit turns dark and the wound shows as a blackish, triangular spot on the green bark. (Pl. VII, *B*.) Several eggs laid on May 24 hatched on May 30, the incubation period being six days.

¹¹ PIERCE, W. DWIGHT. A LIST OF PARASITES KNOWN TO ATTACK AMERICAN RHYNCHOPHORA. In Jour. Econ. Ent., v. 1, no. 6, p. 390. 1908.

¹² *Conotrachelus aratus* Germ., suborder Rhynchophora, family Curculionidae, tribe Cryptorhynchini.

LARVA.

The larva (Pl. VII, *D*, *E*, and *F*) is yellowish white with brown head and black jaws and is covered with scattering, short bristles, those on the dorsal surface of the last three segments being longer than those elsewhere. The length of the larva averages 10 mm. and the thickness at the middle 2 mm. Except for its slightly smaller size it is practically indistinguishable from those of other species described herein.

The favorite feeding place of the larva is in the heart of the bulb-like swelling at the base of the leaf petiole. (Pl. VII, *D* and *E*.) It also mines in the pith of the shoots and leaf stems, making burrows an inch or two long. The season of activity is in the spring and early summer when the new growth is tender.

PUPA.

The delicate, white pupa (Pl. VIII, *B*) is characteristic of the group and occupies an earthen cell from one-half inch to 2 inches below the surface of the ground. The pupa stage covers a period of not more than two or three weeks.

ADULT.

The beetle (Pl. VII, *A*) is considerably smaller than any other of the curculios discussed herein, an average specimen measuring 5 mm. in length and 2 mm. in thickness. The color is dull grayish brown with a more or less indistinct, broad band of yellowish pubescence behind the middle of the elytra and a narrow line of the same color on each side of the thorax. The snout is stout and curved and as long as the head and thorax combined.

The newly transformed beetles issue from the ground in mid-summer and probably spend thereafter a period of comparative inactivity on hickory trees before hibernating in the autumn. With the bursting of hickory buds the following spring they reappear and begin ovipositing as soon as the shoots are a few inches long. They feed rather freely at this time, eating out small pits which extend through the bark of the young growth. Beetles were found frequently hiding between the folds of the expanding buds of hickory. In ovipositing the female spends 30 to 40 minutes in preparing a place for the egg, and while thus engaged is often guarded closely by a male.

NATURAL ENEMIES.

The larvæ while feeding and developing became rather heavily parasitized, at least 50 per cent of them dying from this cause during the two seasons they were kept under observation. Three species of

flies, determined by Dr. J. M. Aldrich as *Myiophasia globosa* Towns., *Cholomyia longipes* Fab., and *Chaetochlorops inquilina* Coq. (Pl. VIII, *D* and *E*), were reared from the larvæ. Two larvæ in rearing cages died when full-grown and from each of their bodies there issued a hairworm several inches long, the species of which was not determined (Pl. VIII, *C*).

METHODS OF CONTROLLING NUT-INFESTING CURCULIOS.

The dropping of curculio-infested walnuts and hickory nuts before the larvæ within them mature affords an opportunity for destroying the young insects by collecting and burning, or otherwise disposing of the fallen nuts. This method can be resorted to with success, however, only in cases of isolated trees or plantations. In localities where the nut trees abound in woods a sufficient number of the curculio beetles will develop on them to visit and injure any near-by plantations of the same kind. Where this means of reducing the insects is practiced collections should be made as often as once a week in order to secure the nuts before the larvæ leave them to enter the ground for the completion of their development.

All the curculios discussed herein do more or less feeding in the beetle stage before oviposition begins in the spring. A considerable part of this food consists of the surface tissues of stems, leaves, and fruit. This makes it possible theoretically to destroy the beetles before their eggs are laid by spraying with arsenical poisons. Limited experiments by the writer indicate that lead arsenate applications soon after growth starts in the spring can be counted on to give good results in reducing injury, at least from the butternut and black walnut curculios.

Britton and Kirk¹³ have found that spraying walnut trees with lead arsenate at a strength of 6 pounds to 50 gallons of water is an effective method of controlling the butternut curculio. Morris,¹⁴ in writing of attacks of the butternut curculio which were so extensive as to kill nearly 300 young English walnuts and several hundred young Japanese walnuts, states that subsequent spraying with 1 pound of lead arsenate to 10 gallons of water killed the beetles and prevented further injury.

¹³ BRITTON, W. E., and KIRK, H. B. Op cit.

¹⁴ MORRIS, ROBERT T. METHOD FOR COMBATING THE WALNUT WEEVIL. In Amer. Nut Journ., v. 10, no. 5, p. 71. 1919.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1067



Contribution from the Bureau of Public Roads
THOMAS H. MacDONALD, Chief

Washington, D. C.

PROFESSIONAL PAPER.

June, 1922

TESTS OF DRAINAGE PUMPING PLANTS IN THE SOUTHERN STATES.

By W. B. GREGORY, *Irrigation Engineer.*

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INTRODUCTION.

Agriculture in the southern portions of Louisiana was first practiced along the rivers and bayous. Since the alluvial soil was deposited by the rivers the highest land is found near the banks, and there is a gradual slope from the rivers and bayous back to the swamp. Previous to the last decade the only reclaimed agricultural lands in southern Louisiana were in the rear of the sugar plantations. The early planters cultivated the narrow strip of land along the streams which could be drained by gravity. The width of these strips varied greatly, but usually the distance from the levees back to the swamp was from one-half mile to 2 miles. The cultivation of sugar cane created a demand for more land, and this demand was met by extending the plantations toward the swamps, removing the water by means of pumps from lands too low to drain by gravity.

About 150,000 acres of agricultural lands in the State of Louisiana have been reclaimed or are at present in process of reclamation. The drainage of these agricultural lands and the drainage of the city of New Orleans, which was largely built in a swamp, have given a notable impetus to the development of pumps and pumping plants in this State. This development has been so rapid that it is now possible to find all types of drainage pumping plants in operation, from the old drainage wheel to the latest design of screw pump. Both

in capacity and in excellence of design the pumping plants of this section are unique, although among the many plants erected there are some that are conspicuously superior to others. Department Bulletin No. 652, "The Wet Lands of Louisiana and their Drainage," and Volume XI, No. 6, of the Journal of Agricultural Research, contain much interesting information relating to the reclamation of these lands.

This bulletin contains a short description of the various types of drainage pumping plants found in the southern coast country, and gives the results of tests that have been made since 1909 by the Division of Agricultural Engineering, Bureau of Public Roads.

TYPES OF PUMPS.

DRAINAGE WHEEL.

The first pumps used in the Gulf Coast country for artificial drainage were of the drainage wheel or scoop wheel type. Many of the steam-driven drainage wheels are still in use in Louisiana. Large wheels of this type range from 28 to 32 feet in diameter, with a width of from 4 to 7 feet. In most localities, however, the cost of foundations stable enough to hold the wheels rigidly in place has increased the cost of the drainage wheels to such an extent that they have been practically eliminated from competition with other cheaper forms of pumping plant. Another point against the drainage wheel is the difficulty involved in adjusting its height. Once set, the depth to which the water may be lowered is definitely fixed. As a rule these wheels are expected to pump against a maximum head equal to one-fourth the diameter. The humus of the drained land in time disappears as the land is cultivated, and the level of the land falls, the amount of shrinkage varying with the depth of humus. As a result of this shrinkage it has been found desirable after a few years to pump to a lower level. With a drainage wheel this requires either lengthening the paddles or lowering the foundations and power plant.

CHAMBER-WHEEL PUMP.

The chamber-wheel pump, certain types of which have been used for drainage, is practically a meter, the discharge being proportional to the speed. Because of the pulsations set up, due to the alternate accelerating and retarding of the water that is being pumped, there are well-defined limits of speed that may not be exceeded without injury to the pump. While the centrifugal pump may be forced to an extent that is limited only by the power of the engine or motor driving it, the limitations of capacity for the chamber-wheel type are found in the pump itself.

CENTRIFUGAL PUMPS.

The centrifugal pump in some of its various forms has proved to be a favorite for drainage work, where large volumes of water must be elevated only a few feet. There are many reasons for the popularity of the centrifugal pump, among which might be mentioned first cost, reliability of operation, simplicity of construction, and its ability, when forced, to develop a capacity much greater than the rated capacity. It is efficient if properly designed for the conditions under which it is operated.

A cheap but fairly efficient form of centrifugal pump that was much used a few years ago is the vertical-shaft, wooden-box pump. Many are still in use, but of late they have given way to more substantial pumps made entirely of metal. The older pumps usually were driven by belt or rope drive, while the modern plants often have pumps and engines direct connected.

HORIZONTAL CENTRIFUGAL PUMPS.

Centrifugal drainage pumps with horizontal shafts ususally have double suction pipes. The suction and discharge pipes with the pump form a siphon, with the pump at the top at a convenient height for examination and for repair. Variations in level of the suction and discharge sides do not affect the pump, and the lift is always equal to the actual difference of level while the head the pump must develop is the lift plus the various friction losses in the pump and piping. These pumps are made by many firms and differ considerably in minor details. Their popularity is shown by the fact that a large majority of all the drainage plants installed during the last 10 years are of this type.

SCREW PUMPS.

Screw pumps range from 3 to 12 feet in diameter, the largest having a capacity of 700 cubic feet per second. The lift ranges up to 10 feet or more.

A combination centrifugal screw pump has been developed that is especially suited to electric motor drive or internal-combustion engines. The blades of this type of pump are so designed that the load is practically constant from a minimum to a maximum lift when running at a constant speed.

SUCTION AND DISCHARGE PIPES.

In drainage installations, where the lift is usually between 4 and 10 feet, the losses at the entrance of suction pipes and the kinetic energy thrown away at the end of the discharge pipe together make up a large percentage of the energy used. These losses increase with the square of the velocity of the water at entrance and discharge,

and the velocity in turn depends upon the diameter or area of the pipe at the two ends. The larger the area at these ends the less will be the velocity and energy loss, and vice versa. For this reason the practice, formerly common, of designing the suction and discharge pipes to have the same diameter throughout is now being very generally abandoned, though occasionally descriptions of such plants, in which the fundamental laws of hydraulics are disregarded, find their way into the technical press.

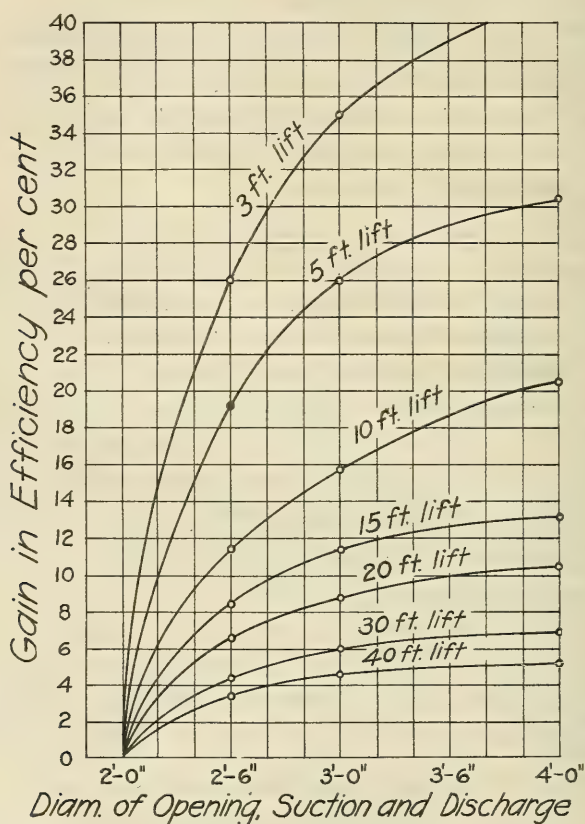


FIG. 1.—Gain in efficiency due to expanding suction and discharge pipes.

Until lately the entrance loss has usually been estimated at 0.93 of the velocity head at the entrance. Bulletin 96 of the Engineering Experiment Station, University of Illinois, contains evidence that this coefficient is too high and suggests a value of 0.62. The discharge loss is equal to the velocity head at the end of the discharge pipe. If the pipes are round and the diameter be doubled at the suction and discharge ends, the areas will be multiplied by 4; and with pumping at a constant rate there will be entrance and dis-

charge velocities one-fourth as great as with pipe of uniform size. Losses vary as the square of the velocity, so they will be reduced to one-sixteenth of the loss in a pipe of uniform size, if the diameter of the ends of suction and discharge pipes be gradually enlarged to twice the diameter of the rest of the pipe, or, in case the pipe is not round, if the end area be increased four times.

The importance of this matter of pipe expansion is illustrated by figure 1. It is assumed that the pump flange is designed for a discharge pipe 2 feet in diameter and that the mean velocity is 10 feet per second. The length of straight pipe is taken as 15 feet.

SOURCES OF POWER FOR PUMPING PLANTS.

STEAM ENGINES.

Steam engines were used to furnish power for the earliest pumping plants. The simpler and less efficient types first employed have been replaced by more efficient types as improved pumps have taken the place of the drainage wheel and less efficient pumps. Plants now in use employ simple, noncondensing engines, compound condensing engines with high-pressure water-tube boilers, Corliss engines direct-connected to centrifugal pumps, and one plant inspected used superheated steam in a compound-condensing engine of the poppet-valve type. Steam plants of all types are reliable in operation, and when the pumps are of the centrifugal type the capacity may be increased to a marked degree, at the expense of efficiency, by merely increasing the speed. Steam plants are easily run and if cared for by a competent operator will have a reasonable length of life.

Unfortunately, however, they frequently do not receive the necessary care. The principal cause of deterioration is the character of water that is used in the boilers. Generally the only water available is the drainage water from the wet prairies, containing acids and organic compounds which corrode and cause trouble with feed pipes, boiler accessories, and boilers.

Besides the boiler troubles to which they are liable steam plants are often wasteful of fuel, while the opposite is true of plants using the internal-combustion engine. For these and other reasons the most recent pumping plants erected in Louisiana have in many instances used internal-combustion engines as a source of power.

INTERNAL-COMBUSTION ENGINES.

In the last few years the internal-combustion engine has been so far improved and perfected that lack of reliability is no longer considered a hindrance to its use. For several years four-stroke cycle engines were used almost exclusively, and the fuels employed varied from heavy low-grade crude oils to kerosene. Recently, two stroke

cycle oil engines of the semi-Diesel type have come into favor. These engines employ comparatively low compression, usually from 125 to 250 pounds per square inch. The speed is relatively high, the engines usually running 200 to 260 revolutions per minute for sizes from 50 to 150 horsepower. They are generally of the horizontal type, but some are of the vertical type. Ignition is by means of a hot bulb or a hot plate partially cooled by water circulation. The details of design differ considerably. In providing scavenging air some compress into the crank case or on the front side of the power piston, while others use a large piston in front of the power piston. Some have governors that may be adjusted while the engine is running, while others must be stopped when an adjustment of the governor is to be made. Some have crossheads, others have trunk pistons. Some inject water with the fuel or into the combustion chamber, others do not. Lubricating oil may be recovered from some of these engines, while that employed in others is useless after being used once. Some owners complain of the large amount of lubricating oil used.

A point worthy of note is that all engines of this type must be operated well under their maximum load to avoid trouble, and this is especially true of the crude-oil engines. The exhaust from engines using crude oil, unless of the Diesel type, is always smoky and often contains tarry matter that will foul the cylinders and eventually cause trouble. Absence of valves tends to minimize this trouble, but does not entirely remove it. Coke sometimes forms in the exhaust pipe if a low grade of oil is used, and the pipe must occasionally be removed and cleaned.

For the smaller plants, two-cycle crude-oil engines are being installed to the exclusion of nearly every other type. The future probably will see some of the present difficulties eliminated, and further use will familiarize operators with such peculiarities as require close attention and care.

ELECTRIC POWER.

Electricity as a source of power for drainage pumping plants has not come into extensive use in southern Louisiana and Texas. It has the advantage of greater convenience than other sources of power, and where adequate transmission lines are easily accessible this advantage may make it desirable, notwithstanding its higher cost as compared with power from steam or internal-combustion engines.

TESTS OF PUMPING PLANTS.

CONDITION OF TESTS.

Tests of pumping plants should be made during fair weather, after allowing the reservoir canals to fill to the maximum depth. If the

test is continued until the water is drawn down to a low level the results may be divided into hourly periods in such a way as to show the behavior of the plant throughout the range of lift. The reservoir capacity per unit tested will determine the length of time required for such a test. If it is desired to determine the behavior of a plant under average lift, either the test must be comparatively short or there must be a supply of water furnished by rain during the test, though the water possibly may be siphoned back through a pump that is not being operated. The latter plan is applicable only to plants having more than one unit. In any case the test usually will be more accurate if it extends over a considerable length of time. Although many of the tests described covered only a comparatively short period, the accuracy of fuel measurements is high because the fuel has been oil. Tests made with this fuel used in internal-combustion engines or burned in boiler furnaces are much more accurate than those made for corresponding periods of time with coal as a fuel. A boiler test with oil fuel can be made without disturbing the normal operation of the plant. With coal as fuel there are many irregularities introduced, due to the measurements necessary to the test. Fortunately all the tests here recorded were made with oil as fuel.

The showing made by a pumping plant depends in some measure on conditions surrounding the test. If a guarantee of efficiency and fuel consumption has been made by the parties erecting the plant and the test is made to show whether the guarantee has been met, the plant is likely to make its best showing. If, however, the same plant has been turned over to a careless operator and has not been kept in first-class condition a casual test made without particular preparation may show results quite different from those of the acceptance test. The amount of this difference will vary greatly with different types of plant and with the conditions of operation.

Centrifugal pumps operate efficiently only at proper speeds. There are, however, many instances where capacity and not efficiency is the controlling element in a pumping plant. If an unusual rainfall has occurred it is desirable to remove the water before damage results to crops, regardless of fuel cost. Steam pumping plants have in general more overload capacity than internal-combustion engine plants. Steam engines usually are selected on a basis of size that enables them to force the pumps beyond normal capacity, while an increase of steam pressure in case of liberal boiler capacity always will insure overloads. On the other hand, the internal-combustion engine usually may not be forced to an output of power greatly in excess of its normal rating. When in the best possible condition a maximum of 10 to 15 per cent in excess of the rating may be expected.

The showing made by a pumping plant will depend to some extent on the amount of vegetation in the water and consequently on the time of year the test is made. A screen in the suction canal to keep weeds from reaching the pump is a necessity. Even where there is a good screen, weeds of small size will pass through and be caught on the blades of the impeller of the pump. The effect is to reduce both capacity and efficiency. There is urgent need for some form of cutter that may be operated while the pump is in use. Such a device has been applied to one form of screw pump. It consists of a heavy cylinder of metal that is forced in and out by a hydraulic piston and so placed that the blades of the impeller barely clear; any trash caught by the blades is thus sheared off and passes on through the pump. The patent involved also covers the application of the device to centrifugal pumps, but so far as observation extends it has not been applied to that type of pump.

Some pumping plants are operated at an improper number of revolutions per minute because of lack of data regarding the proper speeds for different lifts. Without a series of tests to determine the best speed of rotation a plant may be operated at considerable disadvantage. Because of the limited time ordinarily devoted to such a series, and the many limitations affecting the outcome of the tests, it is quite probable that the results do not represent the best performance of the class to which the plant belongs.

The tests described hereafter were run by W. B. Gregory and J. M. Robert, of Tulane University, and C. W. Okey, Senior Drainage Engineer, United States Department of Agriculture, assisted by B. S. Nelson, Charles Kirschner, and several members of the senior class in mechanical engineering at Tulane University.

TEST OF DRAINAGE WHEEL ON THE SOUTH SIDE PLANTING CO.'S TRACT,
NEW ORLEANS, LA.

This test was made in 1905 on a drainage wheel used to drain 1,700 acres. The wheel was typical of its class, but had distinct features in the double gearing and in the number of paddles. Care was exercised so to design the wheel that the water would not be lifted unnecessarily. Its diameter was 28 feet and its width 6 feet. It was driven by a simple noncondensing engine of the slide-valve type, with a cylinder 16 inches in diameter and a stroke of 24 inches.

The method of testing consisted in traversing the discharge flume with a current meter and taking indicator cards and other observations as quickly as possible after the traverse was finished. By this means the indicated horsepower was a little less than the mean corresponding to the water measurement, but as the latter required only about 10 minutes the error was not great.

The results given in Table 1 are very satisfactory, as they show an efficiency of engine, transmission gears, and pump in every case exceeding 38 per cent and in two cases considerably above that figure, while the actual lift of the pump varied from 2.4 feet to 2.86 feet. During the last observation the paddles dipped into the water to a depth of approximately 1 foot, and the slip or backward flow was quite large. The clearance on the side of paddles was about three-fourths inch.

TABLE 1.—*Engine and pump test, South Side Planting Co.'s drainage wheel.*

Boiler pressure.	Indicated horse-power.	Speed of engine.	Speed of wheel.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency.
<i>Lbs. per sq. in.</i>		<i>R. p. m.</i>	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>
40	13.43	61	2.00					
40	12.61	66	2.17	2.4	20.71	9,299	5.59	44.3
38	10.37	68	2.24	2.8	17.20	7,723	5.41	52.2
36	8.80	67.5	2.22	2.7	11.23	5,042	3.41	38.8
37	6.95	68	2.24	2.86	8.21	3,686	2.66	38.3
¹ 38.2	¹ 9.68	¹ 66.1	¹ 2.22	¹ 2.69	¹ 14.34	¹ 6,437	¹ 4.27	¹ 43.4

¹ Mean.

Duration of test, 1 hour.

These results are confirmed by a test of a similar drainage wheel in the old London Avenue pumping station in New Orleans, made in August, 1900, by W. M. White. In this test between 50 and 60 cubic feet per second were pumped through a height varying from 4 to 5 feet. The efficiency of engine, gearing, and pump ranged from 45 to 50 per cent. The duty per 100 pounds of coal was approximately 13,000,000 foot-pounds. The water rate of the engine was 50.5 pounds per indicated horsepower-hour. The engine was of the type used in Mississippi River steamboats; diameter of cylinder 18 inches; length of stroke 54 inches. During the test the engine made about 35 revolutions per minute.

TEST OF CHAMBER-WHEEL PUMP ON WILLWOOD PLANTATION, WAGGAMAN, LA.

In a drainage pumping plant composed of large units such as are required ordinarily in drainage work, the pumps lift the water higher than is necessary, and while they are efficient if credited with the higher lift, they lose their efficiency on low lifts when the actual difference in level is considered.

This point is well illustrated by the test made at the drainage pumping plant of Willwood plantation. At the time there were three pumping units on this plantation, steam being furnished by two water-tube boilers and one horizontal return tubular boiler. The fuel was crude oil and a feed-water heater was used. Following is a description of the three units:

1. A 16 by 24 inch automatic noncondensing engine connected by rope drive to a rotary chamber-wheel pump. Maximum capacity of 40,000 gallons per minute.

2. A similar engine connected by rope drive and bevel gear ¹ to a 42 by 16 inch Menge pump.

3. A double vertical engine direct-connected to a 36-inch centrifugal pump.

Pumps 1 and 2 discharge into open flumes at an average head on the pump of 10 feet, which was 5 feet greater than necessary. The bottom of the discharge flume was placed at the elevation of the top of the back levee, which normally was about 5 feet higher than the water of the swamp behind the levee.

In testing pump No. 1, the quantity of water was measured by means of a weir without end contractions placed in the discharge flume. Table 2 shows the results obtained by the test.

TABLE 2.—*Test¹ of pump No. 1, Willswood plantation, June 15, 1909.*

Boiler pressure.	Indicated horse-power.	Speed.		Discharge.		Actual lift.	Head on pump.	Water horse-power.		Efficiency of engine, transmission, and pump.	
		Engine.	Pump.					Based on actual lift.	Based on head on pump.		
<i>Lbs. per sq. in.</i>		<i>R. p. m.</i>	<i>R. p. m.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	<i>Feet.</i>	<i>Feet.</i>			<i>Per cent.</i>	<i>Per cent.</i>
89	153.5	108.5	89.0	78.2	35,200	5.2	10.0	46.0	88.4	29.9	57.5
89	163.0	115.0	94.5	83.0	37,300	5.3	10.3	49.6	96.5	30.4	59.1
89	155.8	112.5	92.0	80.8	36,300	5.4	10.3	49.3	94.0	31.6	60.3
90	166.8	116.5	95.5	83.9	37,700	5.5	10.5	52.1	99.5	31.3	59.8
92	166.8	117.5	96.0	84.3	37,900	5.5	10.5	52.3	100.0	31.4	60.0
87	152.2	109.0	89.5	78.7	35,400	5.5	10.5	48.8	93.3	32.1	61.3
86	145.6	106.0	87.0	76.4	34,400	5.6	10.5	48.4	90.8	33.2	62.3
										² 31.41	² 60.04

¹ Duration of test, 1 hour and 30 minutes.

² Average.

When the pump was credited with the head through which the water was elevated at the pump the average efficiency of engine, transmission, and pump was found to be 60 per cent. Based on the actual lift it was only 31 per cent. Assuming the mechanical efficiency of the engine as 90 per cent and the efficiency of transmission as 95 per cent, the efficiency of the pump, if credited with the whole lift, is a little more than 70 per cent.

TEST OF MENGE PUMP, PARADIS, LA.

Several efficiency tests of Menge pump installations, both for drainage and for irrigation, show that where the pumps were favorably located and the plants in good condition the efficiencies were excellent.

The results given in Table 3 were obtained from a test of a drainage plant made at Paradis, La. The plant consisted of a 48 by 18 inch Menge pump run by means of a rope drive from a steam engine;

¹ This has since been changed to a quarter-twist rope drive, thus eliminating the bevel gears.

diameter of cylinder 14 inches, stroke 20 inches. Various speeds of rotation were employed for the purpose of finding the best efficiency. The results were excellent and have been confirmed by tests of other plants. If the mechanical efficiency of the engine be assumed as 90 per cent and the efficiency of transmission 95 per cent, the efficiency of the pump would be approximately 55 per cent with a 5-foot lift.

TABLE 3.—*Test¹ of Menge pump, Paradise, La., Sept. 16, 1909.*

Boiler pressure.	Indicated horsepower.	Speed.		Actual lift.	Discharge.			Water horsepower.	Efficiency of engine, transmission, and pump.
		Engine.	Pump.						
<i>Lbs. per sq. in.</i>		<i>R. p. m.</i>	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>			<i>Per cent.</i>
76	11.4	67	78	2.67	1.28	575	0.39		3.4
77	39.6	92	98	3.55	39.6	17,800	15.9		40.2
80	40.1	92	99	3.65	39.6	17,800	16.3		40.6
75	59.6	107	117	4.24	54.5	24,500	26.1		43.8
77	22.1	80	87	3.42	20.8	9,360	8.0		36.2
79	37.7	93	101	3.90	35.5	15,970	15.6		41.4
69	59.3	107	116	4.30	53.7	24,150	26.1		44.0
70	41.7	97	104	4.15	37.9	17,050	17.8		42.7
68	65.8	111	121	4.80	52.0	23,400	28.2		42.8
55	48.4	100	111	4.55	42.8	19,300	22.0		45.5
55	71.0	114	123	5.00	55.5	25,000	31.4		44.2
50	65.3	110	122	5.00	54.5	24,500	30.8		47.1
48	60.6	109	118	4.90	51.2	23,000	28.4		46.8
70	76.5	116	128	5.30	56.3	25,350	33.7		44.1

¹ Duration of test, 3 hours 13 minutes.

TESTS OF PUMPING PLANT OF THE PHILLIPS LAND CO., PLAQUEMINES PARISH, LA.

DESCRIPTION OF PLANT.

This pumping plant is used to drain 2,500 acres of wet prairie land in Plaquemines Parish, about 15 miles below New Orleans. The plant consists of two units, a 36-inch double-suction centrifugal pump driven by a 14 by 18 inch simple slide-valve engine, and a 24-inch double-suction centrifugal pump driven by a 10 by 14 inch simple slide-valve engine. Both engines are noncondensing. The suction pipes of the large pump are 26 inches in diameter, while those of the smaller pump are 18 inches. The pumps are direct connected to the engines through flexible couplings. The exhaust of the engines is conducted through a common exhaust pipe to a closed heater and then to an exhaust head. Steam is furnished by two horizontal return tubular boilers rated at 80 horsepower each. Oil is used as fuel. Steam is required to atomize the oil and to run the oil and boiler feed pumps. The pumping plant is housed in a steel frame building covered with galvanized iron.

METHOD OF CONDUCTING THE FIRST TEST.

The plant was operated under normal conditions for the first test. Fuel was measured in a barrel. Feed water was measured by a Worthington meter, which was calibrated after the test. No attempt

was made to measure the moisture in the steam, the amount of which at times was quite large. Observations were taken at half-hour intervals. The quantity of water pumped was measured by means of Pitot tubes, one being placed in the discharge pipe of each pump. Velocity was measured at 10 points in the pipe, so chosen that the arithmetical mean of the separate velocities gave the mean velocity of water in the pipe.

Gages set in still water in the suction and discharge canals were read, and the difference of the readings used as head of actual lift in computing the useful water horsepower. The heads on the pumps were found by providing openings in the suction and discharge pipes near the pumps and reading the negative heads by means of a mercury column. The suction head was taken in each case as the mean of the two readings on the suction pipes. The head on pump was computed from the formula

$$H = h_d - h_s \pm h'' + \frac{V_d^2 - V_s^2}{2g}$$

h_d = head in discharge pipe in feet of water shown by mercury column; it may be positive or negative.

h_s = head on suction pipe in feet of water shown by mercury column; it is usually negative.

h'' = difference of level of openings in suction and discharge pipes; this term is + if opening in discharge pipe is above that in suction and - when the opposite is true.

V_d = mean velocity in discharge pipe.

V_s = mean velocity in suction pipe.

Table 4 shows the results obtained by the test and Table 5 gives a summary of the results of the engine and pump test and the boiler test.

TABLE 4.—*First test of Phillips Land Co. pumping plant, Oct. 19, 1912.*

36-INCH UNIT.

Time.	Boiler pressure.	Horsepower.	Speed.	Actual lift.		Head on pump.		Discharge.		Useful water horsepower.	Pump horsepower.	Efficiency.	
				<i>R. p. m.</i>	<i>Feet.</i>	<i>Feet.</i>		<i>Sec.-ft.</i>	<i>G. p. m.</i>			<i>P. ct.</i>	<i>P. ct.</i>
	<i>Lbs. per sq. in.</i>												
10:00.....	118	94.0	176	3.85	6.93	62.2	27,910	27.20	48.90	28.9	52.1		
10:30.....	118	92.2	176	4.01	6.61	63.0	28,280	28.70	47.25	31.1	51.3		
11:00.....	117	88.7	172	4.13	6.12	61.2	27,480	28.70	45.80	32.1	50.5		
11:30.....	120	90.9	174	4.21	6.63	61.0	27,390	29.15	45.80	32.1	50.5		
12:00.....	126	90.6	174	4.23	6.63	60.6	27,200	29.60	45.70	32.7	50.4		
12:30.....	120	93.1	177	4.40	6.12	61.2	27,480	30.60	44.40	32.9	50.4		
1:00.....	120	91.6	177	4.49	7.08	61.7	27,700	31.50	49.60	34.4	54.1		
1:30.....	117	88.4	177	4.59	6.76	60.4	27,100	31.45	46.30	35.6	52.3		
2:00.....	120	88.6	176	4.67	6.92	59.5	26,700	31.55	46.70	35.6	52.7		
2:30.....	125	87.8	177	4.77	6.97	54.8	24,600	21.60	43.30	33.7	49.3		
3:00.....	115	86.9	177	4.85	7.26	53.9	24,190	29.65	44.30	34.1	51.0		
3:30.....	118	88.3	175	4.94	7.10	54.2	24,320	30.35	43.60	35.1	50.5		
4:00.....	117	90.3	177	5.04	7.22	50.5	22,670	28.90	41.40	32.0	45.8		
Mean.....	118.5	89.8	175.9	4.48	6.92	58.7	26,345	29.75	45.75	33.2	50.9		

Fuel oil used, both units, 2,256 pounds; feed water used, both units, 27,850 pounds.

TABLE 4.—*First test of Phillips Land Co. pumping plant, Oct. 19, 1912—Continued.*

24-INCH UNIT.

Time.	Boiler pressure.	Horse-power.	Speed.	Actual lift.	Head on pump.	Discharge.		Useful water horse-power.	Pump horse-power.	Efficiency.	
										Based on useful water H. P.	Based on pump H. P.
	<i>Lbs. per sq. in.</i>		<i>R. p. m.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>			<i>P. ct.</i>	<i>P. ct.</i>
10 00.....	118	34.6	210	3.85	6.14	29.5	13,240	12.90	20.60	37.3	59.5
10:30.....	118	35.0	210	4.01	6.20	29.3	13,150	13.33	20.60	38.1	58.8
11:00.....	117	26.0	202	4.13	-----	27.4	12,300	12.85	-----	49.5	-----
11:30.....	120	23.0	182	4.21	5.65	22.6	10,000	10.80	14.50	47.0	63.0
12:00.....	126	23.8	182	4.29	5.72	26.2	11,760	12.72	17.00	53.4	71.5
12:30.....	120	34.1	208	4.40	-----	28.9	12,970	14.43	-----	42.3	-----
1 00.....	120	34.9	209	4.49	6.44	28.7	12,880	14.60	20.90	41.8	59.9
1 30.....	117	33.7	208	4.59	6.57	27.6	12,390	14.40	20.60	42.8	61.1
2:00.....	120	34.1	208	4.67	6.40	27.6	12,390	14.65	20.05	43.0	58.8
2:30.....	125	33.5	208	4.77	6.63	26.5	11,890	14.38	19.95	42.9	59.5
3:00.....	115	33.8	208	4.86	6.33	25.9	11,640	14.25	18.57	42.2	54.9
3:30.....	118	33.4	208	4.94	6.56	26.5	11,890	14.85	19.71	44.4	59.0
4:00.....	117	33.9	209	5.04	6.63	23.6	10,590	13.50	17.78	39.8	52.5
Mean.....	118.5	31.8	204	4.48	6.30	26.9	12,073	13.67	19.10	43.4	59.9

Fuel oil used, both units 2,256 pounds; feed water used, both units 27,850 pounds.

TABLE 5.—*Summary of first test of Phillips Land Co. plant.*

	36-inch unit.	24-inch unit.
ENGINE AND PUMP TEST.		
Duration of test, hours.....	6	6
Revolutions per minute.....	175.9	204.0
Indicated horsepower.....	89.8	31.8
Steam used, pounds per indicated horsepower per hour, average (uncorrected for moisture).....	38.2	-----
Discharge in cubic feet per second.....	58.7	27.5
Discharge in gallons per minute.....	25,350	12,350
Actual lift, feet.....	4.48	4.48
Head on pump, feet.....	6.92	6.30
Head lost in suction and discharge pipes, feet.....	2.44	1.82
Useful water horsepower.....	29.75	13.67
Pump horsepower.....	45.75	19.10
Efficiency of pump, engine, and piping, per cent.....	33.20	43.40
Efficiency of pump and engine, per cent.....	50.90	59.90
Efficiency of pump (engine efficiency assumed to be 90 per cent), per cent.....	56.6	66.6
BOILER TEST.		
Duration of test, hours.....	6	-----
Average steam pressure, pounds per square inch.....	118.5	-----
Total amount of water used, pounds.....	27,850	-----
Total amount of fuel oil used, pounds.....	2,256	-----
Ratio of water to fuel oil (uncorrected for moisture).....	12.35	-----
Average feed-water temperature, degrees F.....	177	-----
Factor of evaporation.....	1.08	-----
Ratio of water evaporated to fuel oil (uncorrected for moisture).....	13.34	-----
Efficiency of boilers (assuming 18,500 B. t. u. per pound of fuel oil), per cent.....	69.7	-----

Two efficiencies are given in Table 5, the first based on the head represented by the difference of level of the suction and discharge basins and the second based on the head on the pump as defined above. The difference between these two amounted to 2.44 feet in the 36-inch unit and 1.82 feet in the 24-inch unit, showing extremely bad design of suction and discharge pipes at the ends where they dip

into the water. By way of comparison, in the test made at Gueydan, La., at the pumping plant of Subdistrict No. 1, Gueydan drainage district, the loss of head corresponding to those given above amounted to 0.3 foot.

SECOND TEST.

A second test was made to determine the efficiency of engine, pump, and piping. This test was of special interest, inasmuch as changes had been made in the suction and discharge pipes of two pumps since the previous test of October 19, 1912. The intake ends of the suction pipes and the exit ends of the discharge pipes as originally constructed were very poorly designed. Since the first test was made the pipes had been replaced by others with well-designed ends. The side clearance of the open impeller of the 36-inch pump, which had been nearly three-fourths inch, had been reduced to about one-eighth inch, and the impeller blades in both pumps had been lengthened.

The changes were beneficial to plant efficiency, although it is difficult to say how much each contributed to the improved conditions. Lengthening the impeller blades and decreasing the clearance gave more water for a given lift and number of revolutions, while the elimination of entrance and discharge losses decreased the total head on pump. The second test was run at a greater lift than was the first, and this also contributed to the higher efficiency. The results of the test are given in Table 6, and a comparison made with the first test in Table 7.

TABLE 6.—*Second test of Phillips Land Co. pumping plant, Aug. 11, 1916.*

36-INCH UNIT.

Time.	Speed.	Indicated horse-power.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency of engine, pump, and piping.
				Sec.-ft.	G. p. m.		
	<i>R. p. m.</i>		<i>Feet.</i>				<i>Per cent.</i>
11.15.....	146	81.20	5.90	64.21	28,800	42.90	52.9
11.20.....	146	81.25	5.95	63.00	28,300	42.50	52.4
11.25.....	146	78.80	6.00	61.40	27,600	41.70	53.0
11.30.....	146	78.60	6.05	62.13	27,900	42.50	54.1
11.35.....	146	80.30	6.10	62.75	28,200	43.30	53.9
11.40.....	138	67.20	6.12	48.53	21,800	33.65	50.2
11.45.....	137	65.72	6.14	47.18	21,200	32.75	49.8
11.50.....	136	62.95	6.16	43.76	19,650	30.55	48.6
11.55.....	135	61.70	6.18	43.08	19,350	30.20	48.8
12.35.....	141	71.65	6.13	59.20	26,600	41.10	57.3
12.45.....	154	93.15	6.20	69.06	31,050	48.50	52.0
12.50.....	153	89.10	6.23	69.03	31,000	48.70	54.7
12.55.....	154	91.60	6.25	69.21	31,100	49.00	53.5
1.00.....	153	91.35	6.29	68.62	30,800	48.90	53.5
1.05.....	160	103.25	6.35	74.48	33,400	53.60	51.8
1.10.....	160	102.50	6.38	74.00	33,250	53.50	52.2
1.15.....	160	101.90	6.42	74.08	33,300	53.80	52.9
Mean.....	148	76.6	6.17	61.98	27,817	43.36	52.45

TABLE 6.—*Second test of Phillips Land Co. pumping plant, Aug. 11, 1916—Contd.*

24-INCH UNIT.

Time.	Speed.	Indicated horse-power.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency of engine, pump, and piping.
	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>
1.35.....	207	33.93	6.25	26.20	11,760	18.55	54.7
1.43.....	206	32.78	6.30	26.38	11,830	18.81	57.4
1.45.....	206	32.02	6.34	25.94	11,640	18.62	58.2
2.00.....	244	50.73	6.44	35.27	15,830	25.72	50.7
2.05.....	244	50.11	6.45	35.93	16,140	26.23	52.4
2.15.....	198	26.83	6.45	21.40	9,610	15.62	58.3
2.20.....	198	26.85	6.45	21.57	9,680	15.72	58.5
2.25.....	199	26.87	6.45	20.72	9,300	15.13	56.2
Mean.....	203	35.01	6.39	26.68	11,974	19.30	55.8

TABLE 7.—*Comparison of the results of the two tests of the Phillips Land Co. plant.*

Unit.	Lift.		Rate of pumping.		Efficiency of engine , pump, and pipe.	
	1912	1916	1912	1916	1912	1916
	<i>Feet.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>Sec.-ft.</i>	<i>Per cent.</i>	<i>Per cent.</i>
36-inch.....	4.48	6.17	58.7	61.9	33.2	52.4
24-inch.....	4.48	6.39	27.5	26.7	43.4	55.8

During the test different speeds were tried. Some of the variations in efficiency are due to change of speed, but the superior efficiencies obtained in the second test bear witness to the great improvement of the pumping units resulting from the changes noted, for the test was made in the same manner and with the same instruments as the first test.

TESTS OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT NO. 6, LAFOURCHE PARISH, LA.

DESCRIPTION OF PLANT.

This plant is used to drain a tract of land containing about 1,880 acres. At the time of the first test the plant consisted of duplicate units, each having a 24-inch double-suction centrifugal pump driven by a 12 by 12 inch simple slide-valve engine. The suction openings on the pumps are 18 inches in diameter. The intake and suction pipes have been tapered and enlarged so that the area of the intake is 4.2 and the area of the discharge 2.7 times the area of the discharge nozzle of the pump. The pumps were direct connected to the engines by flexible couplings. The exhaust of the engines was conducted through a common pipe to a water heater and then exhausted into the air. Steam was generated by two horizontal marine-type boilers 7 feet in diameter by 13 feet long. Neither boilers nor steam line were covered during the test. The fuel used was Mexican crude oil. Steam was used to atomize the oil in the furnaces and to run the

usual oil and boiler feed pumps. The machinery is housed in a corrugated-iron building and is mounted on a concrete foundation supported by piling.

The pumps take the water from the main canal of the district and discharge it into Bayou Des Allemands through about 300 feet of outlet canal. The bulk of the water from the average rain is lifted about 3 feet, so the plant was tested at this lift. When the canals are empty the lift is about 8 feet, but very little water is lifted more than 5 feet. The water on the discharge side varies about 1 foot in height, according to the stage of water in the bayou.

FIRST TEST.

For the first test the plant was operated under normal conditions, using only one of the boilers. Observations were taken at intervals of a half hour. The discharge from the pumps was measured by means of a Pitot tube in each discharge pipe. Gages set in the still water in the suction and discharge canals were read and the actual lift obtained. This lift was used in computing the water horsepower.

The water used in the boiler during the test was measured in a large storage tank. Water was then drawn from this tank and pumped through the heater into the boiler. The oil used as fuel during the test was measured with approximate accuracy in the large storage tank. However, as the tank was about 19 feet in diameter and the oil was lowered only 0.091 foot during the test, it is evident that the oil measurement is only a close estimate, and the error of observation might change the result materially.

The usual method of finding the total head on pump, or dynamic head, was followed, but gave results so erratic that they were considered of no value. The results obtained are set forth in some detail in Table 9. A summary of results is given in Table 8.

TABLE 8.—*Engine and pump test.*

	Unit No. 1.	Unit No. 2.
Duration of test, hours.....	4	4
Revolutions per minute.....	172	162
Indicated horsepower.....	46.8	38.7
Steam used per indicated horsepower, per hour, average pounds.....	40.7	40.7
Discharge, cubic feet per second.....	38.7	37
Discharge, gallons per minute.....	17,340	16,580
Static head, feet.....	2.97	2.97
Useful water horsepower.....	13.01	11.34
Efficiency of pump, engine, and piping.....	28	29.3
Efficiency of pump and piping (assumed engine efficiency, 90 per cent).....	31.1	32.6
BOILER TEST.		
Duration of test, hours.....	4.2	
Average steam pressure, pounds per square inch.....	89.01	
Total water used, pounds.....	14,611	
Total fuel oil used, pounds.....	1,507	
Ratio of water to fuel oil.....	9.69	
Average feed-water temperature, °F.....	155	
Factor of evaporation.....	1.097	
Ratio water evaporated from and at 212° to fuel oil.....	10.63	
Efficiency of boilers (assuming 18,500 B. t. u. per pound of oil), per cent.....	55.6	

TABLE 9.—*First test of pumping plant in subdistrict No. 1, Lafourche drainage district No. 6, Nov. 23, 1912.*

UNIT NO. 1.

Time.	Boiler pressure.	Speed.	Indicated horse-power.	Actual lift.	Discharge.		Water horse-power.	Efficiency.	
								Pump, engine, and piping.	Pump and piping. ¹
	<i>Lbs. per sq. in.</i>	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>	<i>Per cent.</i>
11.45.....	85	164	40.6	2.60	36.5	16,380	10.75	26.5	29.5
12.15.....	92	168	46.4	2.65	40.5	18,180	12.15	26.2	29.1
12.45.....	92	172	46.7	2.72	38.7	17,370	11.92	25.6	28.4
1.15.....	87	174	48.0	2.84	40.7	18,260	13.10	27.3	30.3
1.45.....	86	173	49.1	2.95	39.1	17,550	13.06	26.6	29.5
2.15.....	94	184	55.5	3.07	41.1	18,450	14.30	25.8	28.6
2.45.....	81	170	44.3	3.17	37.5	16,830	13.45	30.4	33.8
3.15.....	92	162	37.6	3.29	34.5	15,490	12.85	34.2	38.0
3.45.....	90	179	53.0	3.42	40.0	17,950	15.50	29.3	32.5

UNIT NO. 2.

11.45.....	85	146	29.0	2.60	30.9	13,870	9.12	31.3	34.7
12.15.....	92	149	30.3	2.65	32.3	14,500	9.70	32.1	35.7
12.45.....	92	150	30.5	2.72	31.8	14,270	9.80	32.1	35.7
1.15.....	87	172	44.4	2.84	35.0	15,710	11.25	25.3	28.1
1.45.....	86	171	44.6	2.95	35.6	15,980	11.90	26.7	29.7
2.15.....	94	175	48.0	3.07	36.2	16,250	12.60	25.0	27.8
2.45.....	81	165	41.0	3.17	34.6	15,530	12.40	30.3	33.7
3.15.....	92	156	34.4	3.29	31.7	14,230	11.80	34.4	38.2
3.45.....	90	172	45.9	3.42	34.9	15,670	13.50	29.5	32.8

¹ Engine assumed to be 90 per cent efficient.

It will be noted that the lift was less than 3 feet, which is much too low for efficient operation of the pumps. The capacity of the pumps was large and they were undoubtedly run too fast to get the best efficiency. By examining Table 9 it will be seen that when the discharge dropped to 30 cubic feet per second the efficiency of pump and piping was about 38 per cent.

SECOND TEST.

At the time of the first test the static lift of the pumps was low, between 2.6 and 3.4 feet, and the pumps were operated at about 30 per cent over their rated capacities. While this information was valuable in showing overload capacity and the efficiency of the pumps at low lift, it was desired to know what efficiency this type of pump would give when operated at the rated capacity and at a static lift of at least 4 feet. The second test made for this purpose included only the engine and pump of unit No. 1. The first reading was taken while the pump was working at a 50 per cent overload and shows the reduction in efficiency that may be expected to result from such an overload. In computing the average efficiency for the test this first reading is omitted. Table 10 gives the results of the test.

TABLE 10.—*Second test, pumping plant in subdistrict No. 1, Lafourche drainage district No. 6, Oct. 23, 1913—Unit No. 1.*

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Actual lift.	Discharge.		Water horsepower.	Efficiency.	
								Pump, engine, and piping.	Pump and piping. ¹
	<i>Lbs. per sq. in.</i>	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec. ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>	<i>Per cent.</i>
12.15.....	90	188	60.15	3.93	45.09	20,200	20.15	33.5	37.2
12.30.....	102	152	33.44	4.01	34.30	15,400	15.56	46.5	51.7
1.00.....	95	144	27.40	4.04	27.77	12,460	12.68	46.3	51.4
1.30.....	100	146	29.73	3.93	32.92	14,780	14.71	49.5	55.0
2.00.....	90	152	31.76	3.84	31.08	13,950	13.56	42.7	47.4
2.30.....	90	151	30.30	3.84	30.74	13,800	13.42	43.8	48.7
3.00.....	96	154	33.05	3.88	30.72	13,790	13.55	41.0	45.5
3.30.....	92	150	30.59	3.88	31.18	13,990	13.75	45.0	50.0
4.00.....	88	150	29.97	3.85	30.37	13,630	13.29	44.3	49.2
4.30.....	90	148	30.00	3.85	30.06	13,470	13.35	44.8	49.8
Average.	94	150	30.69	3.90	31.01	13,920	13.76	44.9	50.0

¹ Engine assumed to be 90 per cent efficient.

The total feed water used in the boiler from 12.15 until 4.30 was 7,590 pounds, or 58.1 pounds per indicated horsepower-hour.

THIRD TEST.

During the fall of 1919 changes were made in the equipment of the pumping plant. A 4-cycle, 50-horsepower Ingeco distillate engine was installed to drive one of the pumps, replacing one of the slide-valve engines. Bevel gears of cast steel, having a ratio of 213 to 164, were used between the pump and engine. The smaller gear was attached to the engine shaft. Both gears were hand-finished and operated with very little noise.

In the test of unit No. 1 of this plant after the above changes the oil used by the engine was carefully weighed, while the output of the pump was measured by means of a Pitot tube in the discharge pipe. The lift was determined from gage readings on the suction and discharge basins. Kerosene oil was used for fuel. Table 11 gives the results of the test.

TABLE 11.—*Third test of subdistrict No. 1, Lafourche drainage district No. 6, Nov. 15, 1919—Unit No. 1.*

Time.	Speed.		Actual lift.	Discharge.		Water horsepower.	Pounds of oil used per 15 minutes.	Pounds of oil used per horsepower hour.
	Engine.	Pump.						
	<i>R. p. m.</i>	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec. ft.</i>	<i>G. p. m.</i>			
11.15.....	212	163	4.27	32.52	14,600	15.73	10.69	2.70
11.30.....	202	156	4.27	29.95	13,450	14.51	10.00	
11.45.....	206	159	4.27	29.95	13,450	14.51	10.50	
12.00.....	209	161	4.27	31.98	14,350	15.50	10.38	
12.15.....	209	161	4.27	31.78	14,250	15.38	10.38	
12.30.....	208	160	4.27	31.70	14,230	15.36	10.12	
12.45.....	208	160	4.27	31.82	14,290	15.41	10.25	
1.00.....	209	161	4.27	32.32	14,520	15.63	10.44	
1.15.....	208	160	4.27	32.14	14,430	15.57	10.06	
1.30.....	215½	166	4.27	31.86	14,300	15.43	10.06	
1.45.....	232	179	4.27	37.37	16,770	18.09	12.09	
2.00.....	227½	175	4.27	36.48	16,370	17.68	12.03	
2.15.....	217	167	4.27	34.62	15,550	16.78	.....	

¹ Variation in speed of engine during this interval.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 3, LAFOURCHE DRAINAGE DISTRICT
NO. 12.

DESCRIPTION OF PLANT.

This plant consisted of duplicate units, each having a 30-inch Lawrence double-suction centrifugal pump driven by a 14 by 16 inch Lawrence vertical slide-valve engine. The suction openings on the pumps are 24 inches in diameter. The intake and discharge pipes have been tapered and enlarged so that the area of the intake is 2.9 and the area of the discharge 1.8 times the area of the discharge nozzle of the pump. The pumps were direct connected to the engines by flexible couplings. The exhaust of the engines was conducted through a common pipe to a water heater and then discharged into the air. Steam was generated by two return tubular boilers of 100 boiler horsepower each. The boilers were in a brick setting covered with asbestos. The fuel used was Mexican crude oil. Steam was used to atomize the oil in the furnaces and to run the usual oil and boiler feed pumps. The machinery was housed in a corrugated-iron building. The average lift was probably less than 3 feet and the maximum lift about 7 feet. The level of the water on the discharge side varied about 2 feet. The area drained is 2,260 acres.

METHOD OF CONDUCTING THE TEST.

It was necessary to siphon considerable water into the district the day before the test in order to have enough water to make a test of both units. As a result the lift was low at first, but rapidly increased to 4 feet at the time of the last reading. A five-hour test was made on unit No. 2, but it was necessary to stop the test of No. 1 after four hours to prevent the débris which had collected around the suction screen from breaking the screen. At noon it was necessary also to shut down one boiler, as the parts of one of the valves in the boiler feed line became detached from the valve stem and jammed so that no water could be pumped into the boiler. By forcing the remaining boiler both pumps were run until the necessary adjustments could be made, although the steam pressure dropped.

The pumps were operated at such speed that they slightly exceeded their rated capacity during the earlier readings. Toward the last, especially after the steam pressure dropped, they were running somewhat under their rated capacity. The discharge of the pumps was measured by means of a Pitot tube in each discharge pipe at distances of about 12 feet from the pump. The first reading taken on unit No. 2 was inaccurate as to quantity pumped, as the velocity of the water was too great to be measured with the Pitot tube.

Gages set in the still water in the suction and discharge canals were read to obtain the actual lift. This lift was used in computing

the useful water horsepower. The indicated horsepower of the engines and the total head on the pump were then obtained in the usual manner. The loss of velocity head due to lack of proper enlarging of the ends of the pipes is quite plainly shown. As this loss varies with the square of the velocity of the water, it is greatest when the pump is working at maximum capacity.

The water used during the boiler test was measured by means of a Worthington piston-type water meter, afterwards calibrated. The steam used for all purposes per horsepower per hour was 54.91 pounds. Table 12 shows the results of the test.

TABLE 12.—*Test of pumping plant in subdistrict No. 3, Lafourche drainage district No. 12, Raceland, La., Nov. 14, 1913.*

UNIT NO. 1.

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Actual lift.	Head on pump.	Discharge.		Useful water horsepower.	Efficiencies. ¹		
									1	2	3
		<i>R. p. m.</i>		<i>Feet.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
9.00.....	100	142	48.4	1.45	2.17	58.18	26,100	9.57	20.0	22.2	33.2
9.30.....	104	143	48.4	1.70	2.67	58.28	26,160	11.25	23.2	25.8	40.5
10.00.....	101	140	46.2	1.95	2.68	54.89	24,630	12.14	26.3	29.2	40.1
10.30.....	102	144	48.9	2.20	2.76	54.84	24,610	13.69	28.0	31.1	39.0
11.00.....	103	144	46.8	2.40	2.98	54.16	24,290	14.76	31.5	35.0	43.5
11.30.....	103	147	49.8	2.75	3.32	54.11	24,280	16.89	33.9	37.7	45.5
12.00.....	106	146	49.1	3.00	3.74	51.60	23,150	17.57	35.8	39.8	49.5
12.30.....	104	142	48.1	3.35	4.23	49.44	22,200	18.80	39.1	43.4	55.0
1.00.....	84	134	39.8	3.62	4.20	42.13	18,910	17.31	43.6	48.4	56.2
Average..	100.8	142.3	47.3	2.39	3.19	53.07	23,820	14.55	.....	.....	.....

UNIT NO. 2.

9.00.....	100	150	88.4	1.45	3.24	66.97	29,900	11.01	12.5	13.9	31.0
9.30.....	104	124	51.6	1.70	3.05	61.08	27,290	11.80	23.0	25.6	46.0
10.00.....	104	124	51.1	1.95	3.30	60.54	27,030	13.41	26.2	29.2	49.3
10.30.....	102	128	53.4	2.20	3.43	59.80	26,720	14.92	27.9	31.0	47.2
11.00.....	101	127	53.2	2.40	3.52	58.28	26,050	15.86	29.8	33.1	48.5
11.30.....	103	127	53.0	2.75	3.77	56.66	25,310	17.67	33.3	37.0	50.7
12.00.....	104	126	52.8	3.00	3.95	55.24	24,690	18.79	35.6	39.5	52.0
12.30.....	104	124	48.3	3.35	4.24	53.67	23,810	20.39	42.2	46.9	59.4
1.00.....	84	120	41.7	3.62	4.32	43.65	19,500	17.92	43.0	47.8	57.0
1.30.....	102	126	50.8	3.90	4.70	41.54	18,570	18.37	36.2	40.2	48.5
2.00.....	108	128	52.1	4.00	4.97	47.14	21,060	21.38	41.1	45.7	56.6
Average..	101.5	127.6	54.2	2.76	3.86	55.00	24,680	16.50	.....	.....	.....

¹ Efficiencies:

1. Efficiency of engine, pump, and piping.
2. Efficiency of pump and piping, assuming mechanical efficiency of engine at 90 per cent.
3. Efficiency of pump, assuming mechanical efficiency of engine at 90 per cent.

As the lift of the pumps was so variable, no average efficiency was determined. A summary of the boiler test follows:

Boiler test.

Duration of test, hours.....	5.08
Total water used, pounds.....	26,760
Total fuel oil used, pounds.....	2,095
Ratio of water to fuel oil.....	12.7
Average steam pressure, pounds per square inch.....	101
Average feed-water temperature, ° F.....	144
Factor of evaporation.....	1.11
Ratio of water evaporated at 212° to fuel oil.....	14.1
Efficiency of boiler (assuming 18,500 B. T. U. per pound of fuel oil), per cent.....	74

TEST OF PUMPING PLANT IN JEFFERSON DRAINAGE DISTRICT NO. 3, LAFITTE, LA.

DESCRIPTION OF PLANT.

This pumping plant is used to drain a tract of about 5,000 acres. The average lift of the pumps is about 4 feet, and at times the maximum lift is 10 feet.

It consists of two 48-inch double-suction centrifugal drainage pumps direct-connected to two 16 by 36 inch simple noncondensing Corliss engines of the girder-frame type. The engines are fitted with gravity release gear and a special governor for emergency use in case the pumps lose their priming. The cut-off is adjustable by hand while the engine is running. Steam is furnished to the engines by two Brownwell horizontal return tubular boilers of 150 horsepower each. The fuel used is Mexican crude oil. For starting the boilers with oil, steam is supplied by a 10-horsepower boiler fired with wood or coal.

The suction and discharge pipes are respectively 25 feet and 20 feet long and are enlarged so that the areas of the intake and discharge are four times the area of the discharge nozzle of the pump. The suction pipes are tapered uniformly from one end to the other, while the discharge pipes are tapered and flattened so that the outer ends have a rectangular cross section with the sides rounded to a radius of 24 inches. A steam ejector is installed on each pump for use in expelling the air in priming.

While this plant was guaranteed to deliver at normal load 55,000 gallons per minute against a total head of 6 feet at a speed of 100 revolutions per minute, it was decided to test it at a much lower total head and somewhat greater capacity and speed.

FIRST TEST.

The first test of this plant determined the capacity and efficiency of the pumps for a rather wide range of heads and speeds. During the test the head increased rapidly, making it necessary to take observations on the pumps as frequently as possible. It was decided that a boiler-test run under such varying conditions would be of little value.

Tests were run on each unit separately. In making the tests indicator cards were taken, the speeds of the engines and pumps were recorded, a Pitot tube traverse was made in each suction pipe, the suction and discharge canal gages were read, and the dynamic head was obtained by means of mercury manometers connected to each suction pipe near the pump flange and to the discharge pipe near the discharge flange.

At the beginning of the test of unit No. 2 the difference in water levels was 3.38 feet. This difference rapidly increased to 6 feet, at which point the attempt was made to keep the speed of the pump as

nearly constant as possible, so as to obtain the efficiency under normal conditions. Table 13 shows the results of the test. The indicated horsepower given in the table is the mean of the two cards taken at the beginning and end of each observation.

TABLE 13.—*First test of pumping plant in Jefferson drainage district No. 3, Lafitte, La., Feb. 22-23, 1913.*

UNIT NO. 1, 48-INCH PUMP.

Speed.	Indicated horsepower.	Discharge.		Actual lift.	Head on pump.	Useful water horsepower.	Efficiency.	
							Pump, engine, and piping.	Pump and engine.
<i>R. p. m.</i>		<i>Sec.-ft.</i>	<i>G. p. m.</i>	<i>Feet.</i>	<i>Feet.</i>		<i>Per cent.</i>	<i>Per cent.</i>
103.....	134.8	136.6	61,300	4.00	4.05	62.0	46.0	46.6
120.5.....	203.5	158.6	71,200	4.40	4.42	79.2	38.9	39.2
101.5.....	121.3	129.8	58,300	4.80	5.48	70.8	58.4	66.6
95.5.....	90.9	103.8	46,600	4.85	5.87	57.1	62.8	.....
100.5.....	102.2	94.6	42,450	6.05	6.58	65.1	63.8	69.3
108.....	137.1	118.3	53,100	5.35	6.29	71.9	52.4	61.6
108.....	142.6	119.7	53,750	5.42	6.23	73.5	51.6	59.4
109.7.....	140.7	122.8	55,100	5.45	6.03	75.9	54.0	59.8
¹ 105.8.....	¹ 134.1	¹ 123.0	¹ 55,200	¹ 5.41	¹ 6.18	¹ 69.4	¹ 52.7	¹ 60.3

UNIT NO. 2, 48-INCH PUMP.

121.....	212.7	170.4	76,500	3.38	4.40	65.4	30.7	40.1
121.....	216.9	176.7	79,300	3.40	3.00	68.2	31.4	35.4
109.....	153.4	147.7	66,300	3.31	4.03	55.5	36.2	44.1
116.....	185.5	158.7	71,250	3.45	5.16	62.1	33.5	50.1
101.7.....	125.5	133.1	59,700	3.64	4.01	55.0	43.8	48.3
93.5.....	95.9	115.4	51,800	3.84	3.71	50.3	52.5	.....
81.5.....	61.0	82.9	37,200	3.70	4.08	34.8	57.1	62.9
114.5.....	163.8	122.1	54,800	6.25	6.84	86.5	52.8	57.8
119.....	174.9	120.1	53,900	6.85	7.17	93.5	53.5	55.9
¹ 108.6.....	¹ 154.4	¹ 136.3	¹ 61,170	¹ 6.55	¹ 7.00	¹ 63.5	¹ 53.2	¹ 56.9

¹ Mean.

In testing unit No. 1 the actual head at the beginning of the test was 4 feet and readings were taken up to 6 feet. It was then found that the increase in head was too rapid to get proper readings, due to the fact that the only water available for pumping was then in the canal. It was therefore decided to siphon water back into the canal with No. 2 unit while testing No. 1. This was done for the last three observations, and as a result the actual head for those three readings was 5.41 feet. The difference between the dynamic and static head gives the friction losses in the pipes and at the entry and discharge. Several inconsistencies appear in the friction losses recorded which can only be accounted for by the fact that it is impossible to make very accurate readings on the suction and discharge manometers of drainage units. Velocities were rather high, and the suction and discharge pipes were so short that there seemed to be a surging effect through the whole system at each revolution of the engine corresponding to the variation in angular velocity at different parts of the stroke.

SECOND TEST.

The results of the second test are given in Table 14. Although they appear to be quite consistent, the quantity of water entering the suction pipe on the engine side was about 50 per cent more than the quantity entering the other suction pipe. This is probably to be attributed to the fact that the end of the suction pipe which had the low capacity was close to the bottom of the canal. The same condition existed during the first test. The water used in the boiler test was measured by a Worthington piston meter. The amount of steam used per horsepower per hour for all purposes was 33.7 pounds. The fuel oil burned during the test was measured in a calibrated barrel.

TABLE 14.—*Second test of pumping plant in Jefferson drainage district No. 3, Lafitte, La., Dec. 13, 1913—Unit No. 2, 48-inch pump.*

Time.	Boiler pressure.	Speed.	Actual lift.	Discharge.		Useful water horsepower.	Efficiency. ¹		Horsepower indicated.
							Pump, piping, and engine.	Pump and piping.	
	<i>Lbs. per sq. in.</i>	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>	<i>Per cent.</i>	
12.00.....	100	115	2.80	125.8	55,750	39.9	23.5	25.5	170.0
12.30.....	100	118	2.90	130.5	58,600	42.8	22.3	24.1	192.9
1.00.....	100	111	2.90	128.0	57,450	42.1	26.5	28.7	159.0
1.30.....	100	113	3.00	130.8	58,720	44.5	25.6	27.9	173.7
2.00.....	100	115	3.10	124.6	55,910	43.8	24.0	25.9	182.8
2.30.....	106	117	3.30	127.2	57,100	47.5	28.2	30.4	168.6
3.00.....	100	110	3.45	125.7	56,410	49.2	32.0	34.0	153.7
3.30.....	100	108	3.60	121.4	54,480	49.6	33.9	36.6	146.5
4.00.....	100	109	3.80	118.6	53,250	51.1	33.9	36.6	151.0
Mean....	100.7	112	3.20	125.8	56,480	45.6	27.8	30.0	166.5

¹ Mechanical efficiency of engine shown by friction cards to be 92.5 per cent.

THIRD TEST.

Nearly three years after the second test a third test was run, this time on No. 1 unit. The useful lift, or actual head, varied from 6.04 to 6.5 feet. The results are given in Table 15.

TABLE 15.—*Third test of pumping plant in Jefferson drainage district No. 3, Lafitte, La., Aug. 14, 1916—Unit No. 1, 48-inch pump.*

Time.	Speed.	Indicated horsepower.	Actual lift.	Discharge.		Useful water horsepower.	Efficiency.	
							Engine and pump.	Pump. ¹
	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>	<i>Per cent.</i>
11.15.....	116	161.7	6.04	110.89	48,900	75.9	46.9	50.7
11.20.....	116	165.9						
11.25.....	117	173.7	6.10	117.29	49,000	81.2	46.7	50.5
11.30.....	116	175.5						
11.35.....	116	168.9						
11.40.....	118	171.8	6.34	113.86	52,600	81.8	47.7	51.5
11.45.....	118	172.3						
11.50.....	117	171.0	6.40	109.02	49,000	79.2	46.3	50.1
11.55.....	118	165.7						
12.00.....	118	167.4						
12.10.....	112	136.9	6.50	94.59	42,900	69.6	50.8	55.0
12.15.....	112	138.4						
12.20.....	114	152.4						

¹ Engine efficiency at 92.5 per cent

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, GUEYDAN DRAINAGE DISTRICT,
FLORENCE, LA.

DESCRIPTION OF PLANT.

This pumping plant is a good example of a high-grade steam plant with simple Corliss noncondensing engines and two 54-inch Worthington double-suction pumps. The pumps are direct connected to two 16 by 36 inch slow-speed Corliss engines, the pump shaft being solid with the engine shaft, thus doing away with flanged couplings. Part of the exhaust is utilized in a 400-horsepower open feed-water heater which raises the temperature of the feed water to 210° F.

The steam-generating equipment consists of two 72-inch by 18-foot return tubular boilers rated at 150 horsepower each and designed for a 125-pound working pressure. Oil is fed to the burners, of which there is one under each boiler, by a pumping outfit which heats and delivers it to the burners at a uniform pressure. The suction and discharge pipes are tapering and well designed.

Each pumping unit has a capacity of 65,000 gallons per minute against a 5-foot difference in level between suction and discharge canals. Each unit has a 40 per cent overload capacity when pumping against a 3-foot head and if necessary is capable of pumping against a 10-foot head with a reduced discharge.

METHOD OF CONDUCTING TEST.

Unit No. 2 of the plant was tested to find the actual operating efficiency. The simultaneous tests which were run on the pumping unit and boiler lasted six hours. The quantity of discharge from the pump was obtained with a Pitot tube. The total head and the actual head on the pump were obtained in the usual way.

During the test it was impossible to utilize the heater, as there was no way of delivering hot water to the weighing barrel. The tank pump was therefore piped to take water from the canal and deliver it into two barrels placed above a third barrel from which the feed pump took suction. The amount of oil used during the test was recorded by an oil meter installed in the oil line to the burners. After breaking the vacuum and draining the pump the mechanical efficiency of the engine was obtained by taking cards from the engine when running at the speed maintained during the test.

During the test the static head was less than 5 feet and the discharge considerably more than 65,000 gallons per minute. These conditions were not those for which the plant was built and undoubtedly resulted in a pump efficiency that is less than it would be under proper conditions. The results of the boiler test are given below and those of the test on the pumping plant in Tables 16 and 17.

Boiler test.

Duration of test, hours.....	6.07
Average stack temperature, °F.....	498
Average steam pressure, pounds per square inch.....	120
Average furnace draft, inches of water.....	0.28
Average feed temperature, °F.....	72
Water evaporated, pounds.....	31,555
Equivalent water evaporated at 212°, pounds.....	37,560
Factor of evaporation.....	1.19
Boiler horsepower developed.....	179.3
Total fuel oil, pounds.....	2,975
Ratio of actual water evaporated to fuel oil.....	10.61
Ratio of equivalent water evaporated at 212°, to fuel oil.....	12.63
Efficiency of boiler (basis 18,500 B. T. U. per pound), per cent.....	66.1

TABLE 16.—*Test of unit No. 2 of pumping plant of subdistrict No. 1, Gueydan drainage district, Florence, La., Oct. 1, 1912.*

Speed.	Indicated horsepower.	Actual lift.	Head on pump.	Discharge.		Useful water horsepower.	Efficiency.	
							Pump and engine.	Pump, engine, and piping.
<i>R. p. m.</i>		<i>Feet.</i>	<i>Feet.</i>	<i>Sec.-feet.</i>	<i>G. p. m.</i>		<i>Per cent.</i>	<i>Per cent.</i>
71	83.8							
81	122.2	5.15	5.81	137.9	61,900	80.5	74.3	65.9
82	132.7	4.85	5.24	155.1	69,600	85.3	69.5	64.3
85	154.5	4.95	5.08	170.9	76,700	96.0	63.8	62.2
89	183.4	4.95	5.08	180.8	81,200	101.5	57.0	55.3
98	225.9	4.95	5.08	200.4	90,000	112.6	51.1	49.9
101	249.7	5.10	5.55	211.9	95,100	122.6	53.3	49.1

TABLE 17.—*Test of engine and pump of unit No. 2 of subdistrict No. 1, Gueydan drainage district No. 1, Florence, La., Oct. 1, 1912.*

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Discharge.		Actual lift.	Head on pump.	Useful water horsepower.	Efficiency. ¹	
									Pump, engine, and piping.	Pump and engine.
	<i>Lbs. per sq. in.</i>	<i>R. p. m.</i>		<i>Sec.-feet.</i>	<i>G. p. m.</i>	<i>Feet.</i>	<i>Feet.</i>		<i>Per cent.</i>	<i>Per cent.</i>
11.15.....	118	90	177.1	185.4	83,200	4.36	4.83	91.6	51.7	57.3
11.45.....	115	89	171.4	188.3	84,500	4.50	4.79	96.2	56.2	59.8
12.15.....	115	91	178.4	194.8	87,500	4.55	4.87	105.0	58.9	60.3
12.45.....	117	90	181.6	190.5	85,500	4.54	5.21	98.4	54.2	62.2
1.15.....	118	89	171.3	195.8	87,900	4.60	5.04	102.4	59.8	65.4
1.45.....	125	94	201.1	198.7	89,200	4.70	4.87	106.0	52.8	54.7
2.15.....	125	94	201.1	199.4	89,500	4.70	4.87	106.4	52.9	54.8
2.45.....	125	91	196.6	194.8	87,500	4.80	5.15	106.2	54.1	58.0
3.15.....	123	92	195.4	195.1	87,600	4.85	5.06	107.5	55.0	57.3
3.45.....	125	92	197.3	190.0	85,300	4.90				
4.15.....	120	91	188.0	192.0	86,200	4.95	5.09	107.6	57.2	58.9
4.45.....	120	91	188.0	184.9	83,000	4.95	5.23	103.9	55.3	58.4
5.15.....	112	90	172.8	181.9	82,100	4.90	5.37	101.6	58.8	64.5
Mean....	120	91.1	196.2	191.8	86,077	4.72	5.02	102.7	55.6	59.9

¹ Pump efficiency was 65.7 per cent, based on 91.1 per cent mechanical efficiency of engine and pump from friction cards.

TEST OF PUMPING PLANT NO. 3, AVOCA DRAINAGE DISTRICT, ST. MARY PARISH, LA.

DESCRIPTION OF PLANT.

This plant is of especial interest, inasmuch as it is the only steam pumping plant in this section in which superheated steam is used. The equipment consists of a cross-compound Lentz engine, a water-tube boiler with 2,487 square feet of heating surface, a 72-inch centrifugal drainage pump with two 48-inch suction pipes, a superheater composed of 2-inch elements about 6 feet 2 inches long (amount of surface unknown), a condenser, a duplex service pump which supplies water to the open heater and to the water seal of the centrifugal pump, and a duplex pump which takes the water from the heater and forces it into the boiler.

The engine cylinder dimensions are $18\frac{1}{2}$ and 31 inches with a 21-inch stroke; the rods are each 4 inches in diameter. The valves are

of the poppet type, operated by eccentrics and cams from a lay shaft with axis parallel to that of the cylinder. The conditions for operating the engine called for a pressure of 175 pounds at the throttle, 200 degrees of superheat, and 26 inches of vacuum. The superheater was not erected in the direct path of the hot gases, and therefore the superheat is less than 200 degrees. The condenser is of the jet type. The boiler walls are lagged with

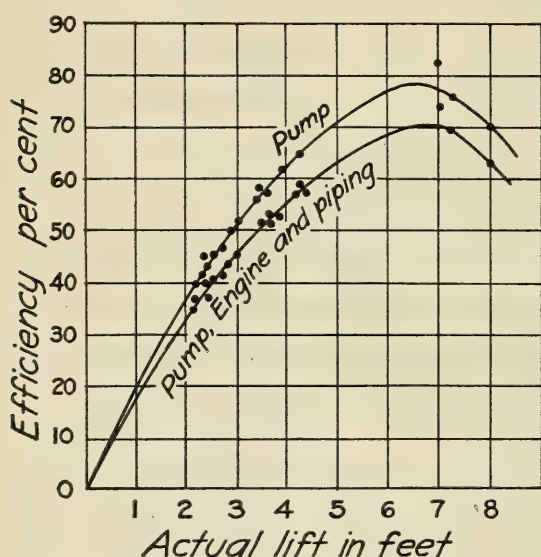


FIG. 2.—Efficiency of pumping plant No. 3, Avoca drainage district, as indicated by test of Sept. 13 and 14, 1914.

cork, which is in turn covered with cement mortar. The suction and discharge pipes of the pump are greatly increased in cross-section at their outer ends.

The test was begun in the morning and continued through the day, but as there was no provision for lighting the plant except by oil lanterns it was discontinued when night came on and resumed the next day.

The oil used during the test was Oklahoma crude oil with a specific gravity of 0.885 at 92° F. The quantity used was weighed in a bucket on a spring balance. The feed water was pumped through a hot-water meter. At the close of the test an attempt was made to cali-

brate the meter, but the results obtained varied about 25 per cent, showing that the water quantities measured are unreliable. Indicator cards were taken on the high-pressure cylinder with an outside-spring Tabor indicator. The thermometer on this cylinder showed an average of 74.5° F. of superheat. The indicator used on the low-pressure cylinder was an inside-spring Thompson. The thermometer on this cylinder indicated an average of 49.2° F. of superheat. A counter attached to the valve gear of the engine, read usually at intervals of 10 minutes, gave the revolutions. The quantity of water pumped was measured by two Pitot tubes inserted in the suction pipes, traverses of the pipes being made at half-hour intervals. Readings of the gages in the suction and discharge canals were taken at half-hour intervals. Table 18 shows the results obtained during the test, and figure 2 is a graph showing the efficiency of the plant at various lifts.

With the exception of the feed-water measurements the test was satisfactory. The only irregularity was due to the presence of air in the pump. As there was nothing to act as a flywheel except the impeller of the pump, there was a tendency for the engine to change speed rapidly on account of pockets of air in the water. This caused considerable variation in the indicator card from the high-pressure cylinder. Because of this variation six cycles were taken for each card, and in this way a very close mean was obtained.

TABLE 18.—*Test of 72-inch unit of pumping plant No. 3, Avoca drainage district, Sept. 13-14, 1916.*

Time.	Boiler. pressure.	Speed.	Indicated horse- power.	Actual, lift.	Discharge.		Useful water horse- power.	Efficiency.	
								Pump, engine, and piping.	Pump.
	<i>Lbs. per sq. in.</i>	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>	<i>Per cent.</i>
10.30.....	146	105.9	188.83	2.22	278.35	125,000	70.05	37.08	41.1
11.00.....	152	106.1	190.68	2.19	276.85	124,100	68.70	36.02	40.4
11.30.....	151	106.0	191.65	2.36	278.08	124,900	74.40	38.80	43.2
12.00.....	153	105.9	187.15	2.46	275.25	123,500	76.45	40.84	45.3
12.30.....	148	105.9	194.28	2.60	273.20	122,600	80.40	41.38	45.9
1.00.....	149	105.9	197.48	2.73	272.05	122,100	84.20	42.63	47.3
1.30.....	149	105.3	196.75	2.86	272.85	122,300	88.40	44.92	49.9
2.00.....	141	105.9	200.70	2.98	272.95	122,500	92.20	45.83	51.1
2.30.....	151	106.1	202.45						
3.00.....	152	105.4	208.15	3.48	269.40	121,000	106.20	51.03	56.6
3.30.....	138	105.8	202.40	3.59	267.65	120,100	108.80	52.43	58.2
4.00.....	156	105.8	214.90	3.68	266.05	119,400	110.90	51.61	57.3
4.30.....	145	105.9	214.85	3.96	264.80	118,800	118.80	55.37	61.4
5.00.....	151	105.6	216.75	4.16	265.00	118,900	124.90	57.65	64.0
5.30.....	148	105.4	216.85	4.23	262.65	117,750	125.80	58.06	64.5
6.00.....	134	105.2	218.15	4.26	259.60	116,500	125.30	57.20	64.0
9.00.....	95	103.9	245.00	7.03	228.00	102,300	181.60	74.18	82.3
9.20.....		104.7	256.03	7.23	217.25	97,700	178.00	69.78	77.4
9.30.....	142	105.2	266.18						74.4
10.00.....	140	105.4	277.40	7.98	194.60	87,300	175.90	63.40	70.3

TEST OF PUMPING PLANT NO. 2, OF AVOCA DRAINAGE DISTRICT, ST. MARY PARISH, LA.

DESCRIPTION OF PLANT.

The equipment of this plant consists of a cross-drum boiler with 1,162 square feet of heating surface, and a Corliss compound condensing engine with cylinder diameters 10 inches and 20 inches and 30-inch stroke with drop cut-off, direct connected to a double-suction centrifugal drainage pump. The pump has a discharge pipe 48 inches in diameter and suction pipes 36 inches in diameter, all pipes measured at the flange. Both the suction and discharge pipes are enlarged at their outer ends.

The test was made with the plant in normal operation. The instruments and methods were the same as those used in the test of pumping plant No. 3 of Avoca drainage district. The average temperatures observed in degrees F. were as follows: Feed water 198°, air 99°, oil 93°, water pumped 80°. The weight of fuel oil used in 2½ hours was 934 pounds. The rate of use was quite regular, and the best economy was shown near the end of the test. Friction cards were taken at the end of the test with no water in the pump. The results are given in Table 19.

TABLE 19.

Revolutions per minute.	Indicated horse-power.
84	8.32
101	11.01
110	13.64

Table 20 gives the results obtained during the test.

TABLE 20.—*Test of pumping plant No. 2, Avoca drainage district.*

Time.	Boiler pressure.	Speed.	Indicated horse-power.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency: Pump, engine, and piping.
	<i>Lbs. per sq. in.</i>	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		<i>Per cent.</i>
2.00.....	115	101.6	123.75	2.76	141.30	63,400	44.2	35.70
2.30.....	130	113.8	125.35	2.81	138.35	62,100	44.0	35.10
3.00.....	135	118.8	170.50	3.41	139.25	62,500	53.8	31.54
3.40.....	127	111.3	149.63	4.45	133.73	60,000	67.4	45.00
4.05.....	127	111.6	150.78	4.93	127.63	57,300	71.3	47.30
4.19.....		112.0	118.95	5.84	110.72	49,700	73.2	61.56
4.30.....	142	108.6	116.69	6.21	99.81	44,800	70.3	60.21

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 4, JEFFERSON DRAINAGE DISTRICT NO. 4, JEFFERSON PARISH, LA.

DESCRIPTION OF PLANT.

In Plate I are shown interior and exterior views of this plant, and figure 3 is a cross-sectional view showing the shape of the suction and discharge pipes and method of supporting the plant. The pumping equipment consists of two duplicate units, each with a capacity of 59 cubic feet per second at a 2-foot lift and capable of pumping at any head between zero and 10 feet, the capacity decreasing as the head increases. The pumps are 30-inch, double-suction, slow-speed drainage centrifugals with special radial and axial flow impellers having a nearly constant horsepower input at all heads. They are direct-connected through friction-clutch couplings to 60-horsepower distillate engines designed to make 190 revolutions per minute and operating on cheap distillate of 39° Baumé gravity.

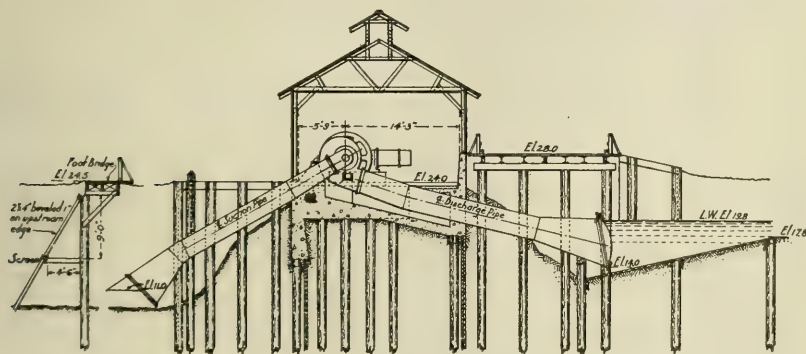


FIG. 3.—Elevation of pumping, subdistrict No. 4, Jefferson drainage district No. 4.

The engines are started on gasoline, run for a few minutes until the jackets warm up, and are then switched to distillate by throwing the handle of a six-way cock. Batteries are unnecessary, as the engines are fitted with oscillating magnetos suitable for starting as well as running, a valuable feature for an isolated plant. Cooling water is supplied by two rotary pumps belted off the hub of the clutch coupling, one to each unit. Each of these pumps is of ample size to supply water to both main engines and to the water-sealed glands of the main pumps. To insure a supply of water for starting and to provide against accidents to the circulating pumps, a 500-gallon elevated tank was erected. This furnished an hour's supply for one engine and is so piped that should the pump stop working, water would still flow to the jackets. An added advantage of this arrangement is that it gives a constant head of water on the jacket at all times.

The suction and discharge pipes on the main pumps are shown in figure 3. These pipes are one-fourth inch riveted steel of such size and design as to reduce the loss of head to about 0.5 foot. This is done by a design of the cross-section of the straight pipe which so reduces the velocity that the friction loss is only 0.25 foot, and by using long taper increasers and liberal bell mouths to reduce the loss due to velocity head. These calculations were made for a normal working head of 4 to 5 feet.

DESCRIPTION OF TEST.

In acceptance test made at this plant, the quantity of water was measured by means of Pitot tubes in the suction pipes. The lift was determined by reading gages in the suction and discharge basins. The fuel was a distillate oil of 42.3° Baumé weighing 6.81 pounds per gallon. The results of the test are given in Table 21.

TABLE 21.—*Test of 30-inch drainage unit No. 2 of the pumping plant in subdistrict No. 4, Jefferson drainage district No. 4, Jefferson Parish, La., Sept. 20, 1916.*

Time.	Speed.	Actual lift.	Discharge.		Oil ¹ used per 20 minutes.	Discharge per gallon of oil.
			Sec.-ft.	G. p. m.	Pounds.	Cubic feet.
11.10.....	R. p. m.	Feet.	49.1	21,900	14.31	28,000
11.30.....	179.6	4.44	42.8	19,180	13.19	26,500
11.50.....	171.9	4.58	48.7	21,800	13.19	30,200
12.10.....	175.4	4.61	46.9	21,000	12.31	31,050
12.30.....	174.9	4.69	43.7	19,600	12.75	28,000
12.50.....	174.8	4.94	43.1	19,300	12.37	28,450
1.10.....	177.0	5.17	42.1	18,830	12.75	26,950
1.30.....	177.1	5.49	41.1	18,400	12.94	25,900
1.30.....	178.6	5.91				
Mean.....	176.2	4.98	44.7	20,060	12.98	28,130

¹ Distillate of 42.3° Baumé; 6.81 pounds per gallon.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT
NO. 9, FAYPORT, LA.

DESCRIPTION OF PLANT.

This pumping plant drains 2,000 acres. The equipment consists of two 30-inch centrifugal drainage pumps, each driven by a kerosene engine of 50-horsepower rating with pistons 16 inches in diameter and the stroke 18 inches. The engines are supposed to run at about 190 revolutions per minute, but ordinarily run at a slower speed. Water is injected with the kerosene. Air tanks are provided for starting, and a small air compressor may be used in charging the tanks. Circulating pumps are belted to the engines.

DESCRIPTION OF TEST.

The test on one unit of this plant was made with the plant operating at from 169 to 182 revolutions per minute. The lift and the quantity of water pumped were measured in the usual manner. The amount

of the fuel oil used was obtained by measuring the change in elevation of the oil in the storage tank. When the test was finished the pump was opened and about a bushel of grass and weeds was taken out. This débris, which must have been accumulated gradually, was nearly equally distributed on the two sides. There were defects in the screen, especially at the ends, but these were soon remedied and it is probable that most of the vegetation came through the screen itself in small pieces. It is certain that the filling up of the pump decreased the capacity and efficiency of the pump. Table 22 gives in detail the results of the test.

TABLE 22.—*Test of pumping plant, subdistrict No. 1, Lafourche drainage district No. 13, Bayport, La., Nov. 24, 1916.*¹

Time.	Speed.	Actual lift.	Discharge.		Useful water horsepower.
			Sec.-ft.	G. p. m.	
10.45.....	<i>R. p. m.</i> 169	<i>Feet.</i> 1.94	35.66	16,000	7.86
11.15.....	168	2.26	33.84	15,200	8.70
11.45.....	169	2.42	30.40	13,630	8.35
12.15.....	170	2.59	30.26	13,590	8.90
12.45.....	170	2.73	28.60	12,830	8.87
1.15.....	182	2.97	31.82	14,300	10.72
1.45.....	181	3.10	29.10	13,060	10.22
2.15.....	182	3.25	29.30	13,140	10.81
2.45.....	182	3.46	28.18	12,620	11.13
3.15.....	181	3.57	26.98	12,100	10.93
3.45.....	181	3.77	24.90	11,170	10.66
4.15.....	183	3.87	25.34	11,370	11.12
Average.....	176.5	2.99	29.53	13,250	10.02

¹ Oil used, 244 pounds.

TEST OF DRAINAGE PUMPING PLANT IN DALCOUR DRAINAGE DISTRICT, DALCOUR, LA.

DESCRIPTION OF PLANT.

This pumping plant installed in 1913 at Dalcour, La., about 22 miles below New Orleans, drains 650 acres of land. A 35-horsepower distillate engine is used to drive a 24-inch centrifugal drainage pump. A friction clutch is used to connect engine and pump. A priming pump is run from a jack shaft which in turn is belted to the engine.

The fuel used in the acceptance test was distillate of 45° Baumé at 86° F., which reduced to 60° F. was equivalent to 42° Baumé, weighing 6.8 pounds per gallon. The manufacturer's guarantee was that the plant would consume not more than 3.56 gallons of kerosene or No. 2 Solar oil per hour with pump operating at a capacity of 9,250 gallons per minute and a difference in water level of 5.5 feet. It was impossible to continue the test long enough to pump the water down to a 5.5-foot lift, but it was agreed that the results obtained at the 5-foot lift would govern if satisfactory. Table 23 gives the results obtained during the test.

TABLE 23.—*Test of pumping plant, Dalcour drainage district, Dalcour, La., May 26, 1914.*

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	
11.10.....	209	4.22	240.0	107,810	} discharge figures should be divided by ten.
11.30.....	210	4.36	233.8	105,000	
11.55.....	209	4.57	230.9	103,700	
12.20.....	209	4.53	218.5	98,200	
12.40.....	212	4.62	225.0	101,000	
1.10.....	211	4.64	224.5	100,800	} Fuel, distillate, 42° Baumé; total oil used from 11.10 a. m. to 2.07 p. m., 78 pounds=3.98 gallons per hour.
1.40.....	211	4.75	223.5	100,400	
2.15.....	212	4.81	218.9	98,300	
Mean....	210.4	4.56	226.9	101,900	
2.50.....	211	4.90	215.4	96,800	} Adjusted carbureter; total oil used from 2.07 p. m. to 4.26 p. m., 45½ pounds=2.99 gallons per hour.
3.25.....	210	5.00	213.4	95,900	
3.45.....	210	5.04	211.0	94,800	
4.40.....	210	5.07	215.1	96,600	
Mean....	210.2	5.00	213.7	96,020	

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT
NO. 20, CUTOFF, LA.

DESCRIPTION OF PLANT.

This plant is made up of two pumping units, each consisting of a 36-inch centrifugal drainage pump driven by a 2-cylinder 4-cycle engine of 120 horsepower at 190 revolutions per minute. The pumps have overhead discharge and are really larger than 36 inches, as they have an oval discharge flange. A flexible coupling is used between engine and pump, but there is no friction clutch. The pumps are primed by means of vacuum pumps run by friction drive from the flywheels of the main engines. The circulating pumps are of the chamber-wheel type. Air tanks and a small compressor driven by a gasoline engine furnish an easy and effective method of starting.

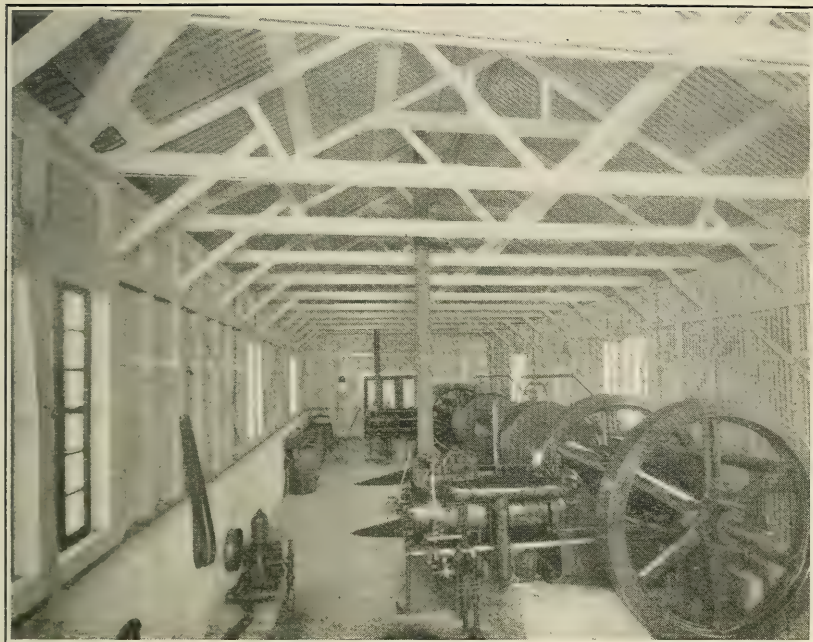
METHOD OF MAKING TEST.

The quantity of water was measured by means of Pitot tubes and the lift was determined by means of gages set in the suction and discharge canals. The fuel used, a distillate of 43.25° Baumé, was weighed by means of a spring balance. The engines were started by gasoline. The results of the test are shown in table 24.

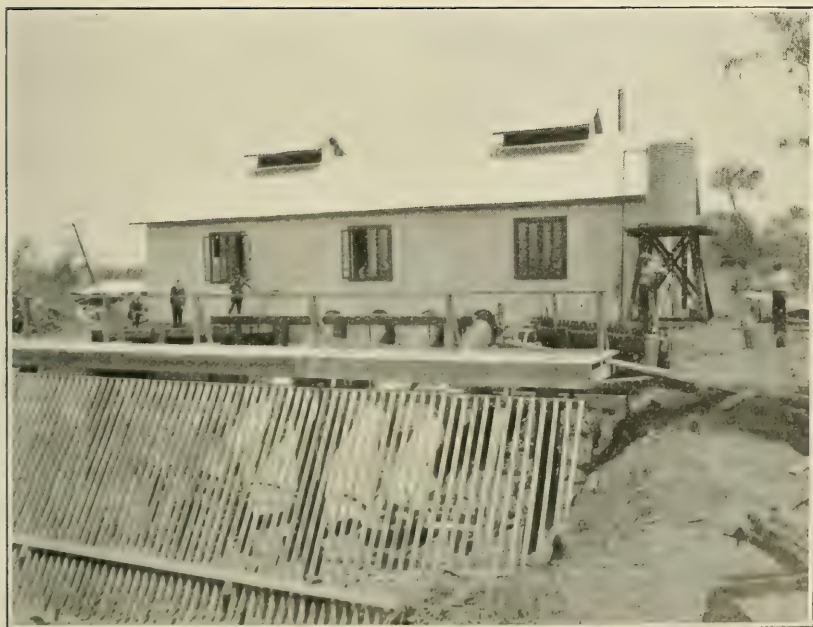
TABLE 24.—*Tests of pumping plant in subdistrict No. 1, Lafourche drainage district No. 20, June 18-22, 1917.*

TEST NO. 1, UNIT NO. 1.

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	
3.50.....	190	4.3	102.8	46,200	} Fuel, distillate of 43.25° Baumé; from 3:49 p. m. to 4:49 p. m., 95.25 pounds of fuel used.
4.05.....	184		100.0	44,860	
4.20.....	188	4.4	99.8	44,700	
4.35.....	187		98.2	44,100	
Mean....	187.2	4.35	100.1	44,965	



D879



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INTERIOR AND EXTERIOR VIEWS OF PUMPING PLANT, SUBDISTRICT NO. 4,
JEFFERSON DRAINAGE DISTRICT NO 4, JEFFERSON PARISH, LA.

TABLE 24.—*Tests of pumping plant in subdistrict No. 1, Lafourche drainage district No. 20, June 18-22, 1917—Continued.*

TEST NO. 2, UNIT NO. 2.

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	
2.40.....	184	5.00	94.0	42,200	* From 3.16½ p. m. to 4.16½ p. m., 98.25 pounds of fuel used.
3.00.....	185	5.15	94.1	42,240	
3.20.....	190	5.25	96.0	43,100	
3.40.....	191	5.35	96.2	43,200	
4.00.....	190	5.45	96.2	43,200	
4.20.....	190	5.55			
Mean....	188.3	5.29	95.3	42,788	

TEST NO. 3, UNIT NO. 2.

12.15.....	190	5.54	94.0	42,220	From 12:07:40 p. m. to 1:42 p. m., 153.7 pounds=97.8 pounds per hour of fuel used.
12.35.....	190	5.60	97.9	43,950	
12.55.....	189	5.74	93.7	42,100	
1.25.....	188	5.84	90.1	40,460	
1.35.....	190	6.07	96.0	43,100	
Mean....	189.4	5.79	94.4	42,366	

SUMMARY.

Test.	Mean actual lift.	Mean speed.	Mean discharge.		Oil per hour.	Water per pound of oil.	Water per gallon of oil. ¹
	<i>Feet.</i>	<i>R. p. m.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	<i>Pounds.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>
1.....	4.35	187.2	100.1	44,965	95.25	3,790	26,630
2.....	5.29	188.3	95.3	42,788	98.25	3,700	26,000
3.....	5.79	189.4	94.4	42,366	97.80	3,480	24,460

¹ Based on 36° oil=7.03 pounds per gallon.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT NO. 12, RACELAND, LA.

DESCRIPTION OF PLANT.

This plant was designed to pump water from 835 acres. It consists of duplicate pumping units, each having a 24-inch double-suction centrifugal pump connected by means of a clutch to a 14.5 by 21 inch 4-cycle engine. The suction openings on the pumps are 18 inches in diameter. The intake and suction pipes have been tapered and enlarged so that the area of the intake and the area of the discharge are considerably greater than the area of the discharge nozzle of the pump. Engine ignition is by means of a hot bulb at the end of the cylinder. Oil is forced into the combustion chamber by means of a pump, and an overflow is arranged so that if the supply is too great the oil will flow back to a tank located in the foundation of the building.

The average lift of the pumps is approximately 3 feet and the greatest lift about 6 feet. The usual variation of the water level on

the discharge side is 2 feet. The suction and discharge pipes are each about 25 feet long, and the main shaft of the pump is about 3 feet above average water level in the discharge canal.

METHOD OF CONDUCTING THE TEST.

Two tests were run on this plant. In the first the discharge of the pumps was measured by Pitot tubes placed in the discharge pipes at a distance of about 10 feet from the pumps. This proved to be so close to the pump that eddy currents interfered with the proper working of the tubes. The results for the quantity of water pumped during the test were found to be too erratic to be of value. A week later the test was run again on one unit with the Pitot tubes placed in the suction pipes. The readings taken on the suction side were very consistent. The lift used in computing the water horsepower was obtained by reading gages set in the suction and discharge canals. The fuel oil used in the engines, a distillate oil of specific gravity 0.875 at 72° F., was weighed in buckets by means of a spring balance.

In the first test the indicated horsepower of the engine was measured by an indicator using a 250 spring. In the second an 80 spring was used with entire success. From 10 to 20 complete cycles were taken on each card and the several areas were averaged. While the results of the first test of the pumps are of no value, the results of the test of the engine compare very well with the results of the second test and are considered of value. Table 25 is a summary of the first engine test.

TABLE 25.

	Unit No. 1.	Unit No. 2.
Length of run, hours.....	4	4
Revolutions per minute, average.....	204	211
Average indicated horsepower.....	32.6	41.6
Minimum indicated horsepower.....	26.4	28.4
Revolutions per minute at minimum indicated horsepower.....	193	183
Maximum indicated horsepower.....	37.7	50.6
Revolutions per minute at maximum indicated horsepower.....	213	221
Total pounds of fuel oil Nos. 1 and 2.....	219.2	
Pounds of fuel oil per indicated horsepower-hour.....	.74	
Pounds per brake horsepower (assuming mechanical efficiency of 80 per cent.).....	.92	

During the second test on unit No. 1 the speed of the engine was somewhat less than in the previous test, and the engine seemed to be working much more smoothly. The results of the test are given in Table 26.

TABLE 26.—*Test of pumping plant in subdistrict No. 1 of Lafourche drainage district No. 12, Raceland, La., Nov. 22, 1913.*

Time.	Speed.	Indicated horse-power.	Actual lift.	Discharge.			Water horse-power.	Efficiency. ¹		Fuel used per one-half hour.
								1	2	
	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>			<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>
8.45.....	205	31.4	2.18	36.44	16,370		8.97	28.6	35.7	-----
9.15.....	206	34.0	2.25	35.78	16,060		9.14	26.9	33.6	11.00
9.45.....	201	32.2	2.47	34.49	15,445		9.60	29.8	37.2	10.44
10.15.....	206	33.8	2.73	34.36	15,430		10.45	31.6	39.5	20.31
10.45.....	204	34.1	3.05	33.62	15,100		11.70	34.3	42.8	10.56
11.15.....	205	34.5	3.29	33.15	14,885		12.41	35.0	43.7	13.75
11.45.....	210	34.5	3.54	33.64	15,110		13.52	39.2	49.0	13.62
12.15.....	212	35.4	3.82	32.82	14,740		14.22	40.3	50.5	13.00
12.45.....	215	35.9	4.12	31.46	14,120		14.65	40.8	51.0	12.87
Mean..	207	34.0	3.05	33.97	15,245		11.52	34.1	42.6	13.19

¹ Efficiency: (1) Efficiency of pump, piping, and engine. (2) Efficiency of pump and piping, assuming mechanical efficiency of engine to be 80 per cent.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 2 OF LAFOURCHE DRAINAGE DISTRICT NO. 12, RACELAND, LA.

This pumping plant contains two units similar to those at Raceland subdistrict No. 1 and similar methods of testing were used. The pumps and accessories are practically the same, but the engines, while of the same type and make as those in the previously described plant, have a cylinder diameter of 15 inches with 24-inch stroke. The pumps are 24-inch drainage pumps of the centrifugal type. The behavior of the engine in this test was doubtless affected by the presence of some Mexican crude oil which had been put in the tank more than a year before.

The indicator cards, when taken for several cycles, showed two different areas: One area was the regular card, while the other showed a rise in the compression line earlier than in the large card and no great increase of pressure at the end of compression, but a gradual rise of pressure as expansion proceeded until at exhaust opening the pressure was about the same as for the large card. There was no accurate way to determine how often either of these cards occurred. The evidence from a great many cards showed that the numbers of large and small cards were about equal, but this was too uncertain to make the indicated horsepower reliable enough to compute pump efficiency. Owing to the behavior of the engine the speed of pump was quite variable. Table 27 gives the results obtained.

TABLE 27.—*Test of pumping plant in subdistrict No. 2 of Lafourche drainage district No. 12, Raceland, La., Apr. 19, 1915.*¹

Time.	Speed.	Actual lift.	Discharge.		Water horse-power.
	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	
9.15.....	198	3.67	29.44	13,210	12.24
9.45.....	198	3.81	26.08	11,720	11.27
10.15.....	200	3.98	31.17	14,000	14.05
10.45.....	200	4.14	23.11	10,420	10.83
11.15.....	198	4.34	29.42	13,230	14.48
11.45.....	200	4.49	22.53	10,110	11.45
Average.....	199	4.07	26.96	12,100	12.46

¹ Fuel-oil consumption, 23.4 pounds per hour.TEST OF JAMISON RELIFT PLANT OF THE LOUISIANA IRRIGATION & MILL CO.,
CROWLEY, LA.

This pumping plant contains two units, each consisting of a 60-horsepower Muncie engine direct-connected to a 36-inch centrifugal pump. The pumps are primed by small vacuum pump run from the engines. A small compressor and a gasoline engine are used to fill the air tanks for starting the engines. Although used for irrigation, this pumping plant does not differ in any way from plants used for drainage.

Tests were run on both units of the plant. The results are given in Table 28. The quantity of water pumped was measured by a current meter in a carefully constructed flume in the suction canal. The lift was determined by means of gages set in suction and discharge canals. Fuel oil was accurately weighed by a spring balance.

TABLE 28.—*Tests of Jamison relift pumping plant of Louisiana Irrigation & Mill Co., Crowley, La., May 18-19, 1917.*

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	
3. 00.	259	3. 57	51. 9	23, 300	In the first hour 31.44 pounds of oil were consumed. The number of gallons pumped per pound of oil was 43,940; total oil consumption 54.06 pounds.
3. 15.	261	3. 54	51. 7	23, 200	
3. 30.	256	3. 52	49. 9	22, 400	
3. 45.	256	3. 50	51. 7	23, 200	
4. 00.	256	3. 52	50. 8	22, 800	
4. 15.	256	3. 51	50. 1	22, 500	
4. 30.	256	3. 53	50. 2	22, 550	
Average..	257	3. 53	50. 9	22, 855	
9. 00.	255	2. 04	52. 3	23, 500	The total consumption of oil was 29.81 pounds per hour; gallons pumped per pound, 47,750.
9. 15.	255	2. 03	53. 5	24, 000	
9. 30.	256	2. 01	53. 2	23, 900	
9. 45.	255	1. 99	52. 3	23, 500	
Average..	255. 2	2. 03	52. 8	23, 725	
1. 45.	258	2. 20	49. 5	22, 200	Consumption of oil, 32.87 pounds per hour; gallons pumped per pound, 40,200.
2. 00.	257	2. 13	49. 3	22, 100	
2. 15.	256	2. 10	48. 3	21, 700	
Average..	257	2. 14	49. 0	22, 000	

TESTS OF THE FERRE, HINE'S, AND RICHARD RELIFT PUMPING PLANTS OF THE LOUISIANA IRRIGATION & MILL CO., CROWLEY, LA.

During the summer of 1919 the Louisiana Irrigation & Mill Co. installed several pumping units in relift plants. Tests were made to determine the performance of these pumping units, with results as shown in Tables 29, 30, and 31. The equipment in each plant consisted of duplicate units made up of 60-horsepower internal-combustion engines direct-connected to 24-inch centrifugal pumps.

TABLE 29.—*Test of Ferre relift pumping plant, Grand Canal, July 9, 1919.*

[60-horsepower Ingeco engines direct-connected to 24-inch Worthington pumps.]

Time.	Speed of pump.	Actual lift.	Minutes required to use 12 pounds of oil.	Discharge.	
	<i>R. p. m.</i>	<i>Feet.</i>		<i>Sec.-ft.</i>	<i>G. p. m.</i>
South unit:					
9.50.....	238.0	3.99	.....	45.00	20,200
10.10.....	238.5	4.00	.....	45.90	20,600
10.30.....	236.0	4.04	21.0	45.62	20,480
10.50.....	241.0	4.06		45.12	20,250
11.10.....	240.0	4.06	20.5	45.12	20,250
11.30.....	241.5	4.08	20.5	41.98	18,850
11.50.....	243.5	4.08	20.0	42.40	19,030
Average.....	239.9	4.04	20.6	44.60	20,080
North unit:					
2.50.....	233.0	4.40	20.5	44.59	20,000
3.10.....	228.0	4.39	22.5	45.00	20,200
3.30.....	231.5	4.38	22.5	41.65	18,700
3.50.....	236.0	4.35	22.5	43.22	19,400
4.10.....	231.0	4.33	22.5	42.12	18,900
4.30.....	231.5	4.33	22.5	42.21	18,950
4.50.....	233.5	4.33	22.0	44.10	19,900
Average.....	232.1	4.36	22.1	43.28	19,420
Oil corrected for drip.....			22.6		

TABLE 30.—*Test of Hine's relift pumping plant, Grand Canal, July 12, 1919.*

[60-horsepower Bessemer engine belted to 24-inch Lawrence pump.]

Time.	Speed.		Actual lift.	Minutes required to use 12 pounds of oil.	Discharge.	
	Engine.	Pump.				
	<i>R. p. m.</i>	<i>R. p. m.</i>	<i>Feet.</i>		<i>Sec.-ft.</i>	<i>G. p. m.</i>
4.00.....	222.0	167.5	7.38	30	18.24	8,190
4.15.....	217.0	166.0	7.37	.....		
4.30.....	217.0	166.0	7.33	.....		
4.45.....	217.0	167.0	7.33	30		
5.00.....	220.0	169.0	7.33		27.18	12,200
5.15.....	255.0	193.0	8.33	19		
5.30.....	256.0	198.5	8.37	.....		
5.45.....	255.5	199.0	8.40	18		
6.00.....	256.0	198.0	8.41	.....		
6.15.....	260.0	198.5	8.43	18		

TABLE 31.—*Test of Richard relift pumping plant, Grand Canal, July 11, 1919.*

[60-horsepower Ingeco engine direct-connected to Worthington pumps.]

Time.	Speed.		Actual lift.	Minutes required to use 12 pounds of oil.	Discharge.	
	No. 1.	No. 2.				
	<i>R. p. m.</i>	<i>R. p. m.</i>	<i>Feet.</i>		<i>Sec.-ft.</i>	<i>G. p. m.</i>
1.40.....		250.0	7.75	-----	39.65	17,800
2.00.....		250.0	7.84	19.5	38.65	17,350
2.20.....		250.0	7.87	20.5	38.65	17,350
2.40.....		249.0	7.85	21.0	36.60	16,450
Average.....		249.7	7.83	20.33	38.38	17,237

The methods followed in testing the Ferre relift and the Richard relift were the same as those already described in the test of the Jamison relift. In making the test of the Hine's relift the quantity of water was measured by means of a weir installed at the end of the flume. As the flow was rather turbulent, the depth on the weir could not be read with great accuracy, and the results may be in error by 5 per cent. As the water was discharged vertically upward from the pump, the discharge gage could not be read as accurately as in the other test, but the readings are substantially correct and the final results satisfactory.

Fuel oil used in these plants was Jennings crude, direct from the wells. A sample from the Richard relift had specific gravity 0.8975 or 26.15° Baumé at 100° F.

DRAINAGE PUMPING PLANT AT PORT ARTHUR, TEX.

This plant was installed to drain the city of Port Arthur, an area of approximately 2,175 acres. It is not an agricultural proposition and the capacity is far in excess of that required for farm lands. The pumping plant contains three units, each consisting of a vertical 2-cylinder 100-horsepower oil engine direct-connected to a 48-inch screw pump. Two of the pumps were sold under a guaranty to deliver 40,000 gallons per minute against a 5-foot lift and 26,000 gallons per minute against an 11-foot lift. The other pump was to deliver 55,000 gallons per minute against a 5-foot lift. All operate at 257 revolutions per minute.

In the test of this plant, water measurements were made with a Pitot tube. The lift was determined by means of gages set in suction and discharge basins. Fuel oil was measured by means of a spring balance. Readings of fuel were taken at 5-minute intervals. The oil used was sold as 28° Baume, weight 7.38 pounds per gallon.

Tests were made on one high-lift and on the low-lift unit. In the course of the work of adjusting and testing the plant it was found that the blades were quite rough. When they were made smooth and sharp a marked improvement in capacity and duty was observed.

Table 32 gives the result of a test on high-lift unit No. 2 before the blades of the pump were smoothed and sharpened. Table 33 gives the results of a test after the improvements had been made. It was believed that a considerably better showing would be obtained from the low-lift pump by sharpening the impeller blades and trimming out the casing, and this work was subsequently done. The results of the test on low-lift unit No. 3 are given in Table 34.

TABLE 32.—*Test of pump No. 2 of drainage pumping plant at Port Arthur, Tex., July 23-26, 1918.*¹

Time.	Speed.	Discharge.		Actual lift.	Fuel used.	Water pumped per gallon of fuel used.
	<i>R. p. m.</i>	<i>Sec. ft.</i>	<i>G. p. m.</i>	<i>Feet.</i>	<i>G. p. m.</i>	<i>Gallons.</i>
2.56.....	255	89.12	40,000	4.75		
3.00.....	255	88.68	39,800	4.95	0.139	286,000
3.05.....	255	88.23	39,600	5.15	.166	238,000
3.09.....	254	87.56	39,300	5.38	.164	239,000
3.15.....	254	85.56	38,400	5.60	.156	246,000
3.19.....	254	86.01	38,600	5.75	.163	237,000
3.23.....	252	85.34	38,300	6.05	.175	219,000
3.32.....	252	84.00	37,700	6.68	.159	237,000
3.37.....	250	81.10	36,400	7.18	.180	202,000
3.45.....	244	78.65	35,300	8.64	.210	168,000
3.49.....	239	71.30	32,000	10.10	.213	150,000
3.53.....	237	58.87	26,200	11.34	.210	125,000

¹ This test was made W. P. Langworthy before pump blades were sharpened.

TABLE 33.—*Test of pump No. 2 of drainage pumping plant at Port Arthur, Tex., July 23-26, 1918.*¹

Speed.	Average velocity of flow.	Discharge.		Actual lift.	Fuel used.	Water pumped per gallon of fuel used.
<i>R. p. m.</i>	<i>Ft. per sec.</i>	<i>Sec. ft.</i>	<i>G. p. m.</i>	<i>Feet.</i>	<i>G. p. m.</i>	<i>Gallons.</i>
254	6.04	89.12	40,000	3.60	0.153	262,000
255	5.87	86.45	38,800	3.75	.156	219,000
253	5.89	86.67	38,900	3.88	.156	249,000
254	6.09	89.57	40,200	3.97	.151	267,000
253	5.91	87.12	39,100	4.35	.154	254,000
253	5.77	85.11	38,200	4.40	.154	248,000
253	5.82	85.78	38,500	4.48	.149	258,000
254	5.85	86.22	38,700	4.60	.149	260,000
253	5.81	86.56	38,400	4.70	.159	211,000
252	5.85	86.22	38,700	5.00	.164	236,000
252	5.70	84.00	37,700	5.18	.164	230,000
252	5.64	83.33	37,400	5.40	.166	225,000
252	5.61	82.88	37,200	5.60	.173	215,000
251	5.44	80.21	36,000	5.82	.173	208,000
249	5.53	81.55	36,600	6.45	.180	203,000
247	5.51	81.32	36,500	6.70	.180	203,000
245	5.48	80.65	36,200	7.10	.169	214,000
243	5.24	77.31	34,700	7.65	.169	205,000

¹ This test was made W. P. Langworthy after pump blades were sharpened.

TABLE 34.—*Test of pump No. 3 of drainage pumping plant at Port Arthur, Tex., made by W. P. Langworthy July 23-26, 1918.*

Time.	Speed.	Average velocity of flow.	Discharge.		Head.	Fuel used.	Water pumped per gallon of fuel used.
	<i>R. p. m.</i>	<i>Ft. per sec.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>	<i>Fest.</i>	<i>G. p. m.</i>	<i>Gallons.</i>
11.28½	250	7.91	116.75	52,400	3.00	0.160	327,000
11.36	250	7.84	115.41	51,800	3.38	.157	330,000
11.51	249	7.79	114.75	51,500	3.86	.166	310,000
11.55	246	7.60	112.07	50,300	3.96	.173	291,000
11.59	246	7.51	110.51	49,600	4.06	.174	285,000
12.03	246	7.29	107.39	48,200	4.19	.178	271,000
12.07	245	7.36	108.28	48,600	4.36	.194	250,000
12.15	241	7.27	107.17	48,100	4.63	.174	276,000
12.19	243	7.28	107.39	48,200	4.76	.183	263,000
12.23	244	7.26	106.95	48,000	4.90	.184	261,000
12.27	243	7.21	106.28	47,700	5.00	.163	293,000

TEST OF DRAINAGE PUMPING PLANT IN SUB-DISTRICT NO. 4, LAFOURCHE DRAINAGE DISTRICT NO. 12, RACELAND, LA.

This plant, which drains 4,466 acres of prairie land, was installed in 1915. The machinery consists of two units, duplicates in every way except that the pumps are driven respectively by right-hand and left-hand engines. The pumps are 48-inch centrifugal drainage pumps designed for high speed and a flat power curve. The pump impellers are a combination of the screw propeller and the ordinary centrifugal pump impeller. Each pump has double-suction pipes attached to 48-inch elbows, and both suction and discharge pipes are enlarged at their outer ends. Wooden flap valves are used to cover the discharge ends while the pumps are being primed.

The pumps are driven by 2-stroke cycle Diesel engines 14½ by 24 inches, with variable speed governors. The plant is ordinarily operated between the limits of 190 to 200 revolutions, while for maximum lift of about 9 feet the speed may be increased 220 revolutions per minute.

A test of one of the units was made to determine the oil consumption for a given output of work. Observations were taken every 20 minutes on the speed, lift, suction (with manometers), pounds of oil consumed, and quantity of water pumped. The fuel used during the test was crude oil, specific gravity 0.889, or 27.4° Baumé at 60° F.

The unit tested was situated on the left-hand side of the suction canal looking upstream. The two suction pipes are labeled right and left, as one stands facing the suction canal, and therefore the right-hand suction pump is near the middle of the canal. During the test an eddy was observed in the suction basin, so disposed that water was brought to the right-hand pipe and away from the opening of the left-hand suction pipe. The effect of the eddy was clearly shown in the quantities of water measured in the two pipes, as the right-hand pipe invariably carried more water. Without doubt this condition

had some effect upon the efficiency of the pump, and consequently reduced the over-all efficiency. The eddy was caused by unequal depths of water below the suction pipes and by the higher velocity near the center line of the suction canal.

RESULTS OF TEST.

The test, which extended over a period of nearly six hours, was run with a varying difference of levels in the canals, the lift increasing from 3.55 feet at the beginning of the run to 4.96 feet at the close. The speed of the pump was held uniform at 195 revolutions per minute, but the total water pumped varied with the change in actual lift, ranging from 60,050 gallons per minute at the lower lift (3.55 feet) to 54,700 gallons per minute at the higher lift (4.96 feet). The results obtained are given in Table 35.

The economy of the plant can best be realized by a comparison with the steam pumping plant in subdistrict No. 1, Gueydan drainage district, where the equipment consists of high-grade simple noncondensing Corliss engines and volute pumps. When pumping against a head of approximately 5 feet the fuel consumption of the steam plant was to that of the internal-combustion engine plant as 4.28 to 1 for equal output of work.

TABLE 35.—*Test of pumping plant in subdistrict No. 4 of Lafourche drainage district No. 12, Raceland, La., Feb. 21, 1916.*

Time.	Speed.	Actual lift.	Discharge.			Useful water horse-power.
	<i>R. p. m.</i>	<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>		
9. 40.....	195					
10. 00.....	196	3. 55	133. 80	60, 050		53. 80
10. 20.....	195	3. 63	132. 79	59, 600		54. 70
10. 40.....	195	3. 69	131. 57	59, 050		55. 00
11. 00.....	195	3. 75	131. 23	58, 900		55. 80
11. 20.....	195	3. 82	128. 23	57, 550		55. 50
11. 40.....	195	3. 90	128. 89	57, 850		56. 95
12. 00.....	195	3. 98	129. 90	58, 300		58. 60
12. 20.....	195	4. 08	126. 22	56, 650		58. 40
12. 40.....	195	4. 17	126. 78	56, 900		59. 90
1. 00.....	195	4. 27	128. 67	57, 750		62. 25
1. 20.....	195	4. 34	125. 00	56, 100		61. 50
1. 40.....	195	4. 43	124. 66	55, 950		62. 55
2. 00.....	195	4. 52	126. 00	56, 550		61. 55
2. 20.....	195	4. 63	125. 55	56, 350		65. 90
2. 40.....	195	4. 74	123. 88	55, 600		66. 50
3. 00.....	195	4. 84	123. 32	55, 350		67. 60
3. 20.....	195	4. 96	121. 88	54, 700		68. 50

TEST OF DRAINAGE PUMPING PLANT OF LITTLE WOODS TRACT, NEW ORLEANS, LA.

DESCRIPTION OF PLANT.

The New Orleans Lake Shore Land Co. has reclaimed an area of 6,943 acres of prairie land, located on Lake Pontchartrain, inside the city limits of New Orleans. The pumping plant was erected during the latter part of 1913. (See Pl. II.) It consists of two centrifugal pumps, each with a discharge opening equivalent to a circle of 54½ inches diameter, connected by means of herringbone gears to electric

motors. Electric energy was used in this case because of the desirability of having the city current for use for other power and in the suburban residences. The cost of electrical energy is greater than that of steam power or that furnished by internal-combustion engines, although the first cost of the electrical plant is less than either of the other types. The plant is very economical when interest on investment and depreciation are considered together with the cost of operating.

The pumps are equipped with a combination of screw and inclosed-centrifugal impeller. They are primed by means of small exhaust pumps of the chamber-wheel type driven by small motors. Greatest capacity is had at the low lifts, where it is desirable. As the lift increases the capacity decreases, but the need of large capacity also decreases. The capacity of the plant when operating at a lift of 4.5 feet is 1.3 inches in depth removed from the area in 24 hours. The motors which drive the pumps run at practically constant speed, and therefore the revolutions of the pump remain constant regardless of lift.

METHOD OF MAKING TEST.

The height through which the water was elevated was obtained by reading gages in the suction and discharge basins. The quantity of water was determined by using a Price current meter in the discharge flume. The voltage and revolutions per minute were also observed. The results of the test are given in Table 36. It is believed that the two units under favorable conditions will show identical results.

TABLE 36.—*Test of pumping plant in Little Woods Tract, New Orleans, La., Nov. 14, 1914.*

UNIT NO. 1.

Time.	Speed.	Volts.	Actual lift.	Discharge.		Kilo-watts.	Electrical horse-power.	Water horse-power.	Efficiency.
	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>				<i>Per cent.</i>
10.00.....	119.8	2,246	5.76	173.7	77,800	174.0	233.0	113.5	48.80
10.15.....	121.2	2,288	5.83	176.8	79,200	174.9	234.2	116.8	49.75
10.30.....	120.7	2,300	5.85	177.9	79,700	174.8	234.2	118.0	50.35
10.45.....	120.7	2,298	5.85	175.5	78,600	175.1	234.6	116.2	49.50
11.00.....	121.2	2,298	5.87	173.7	77,800	175.0	234.5	115.5	49.25
11.15.....	121.4	2,304	5.91	172.1	77,100	178.0	238.5	115.3	48.35
3.15.....	120.8	2,320	6.29	171.0	76,600	174.4	233.7	121.8	52.10
3.30.....	120.5	2,320	6.39	169.2	75,800	172.6	231.3	122.7	53.10
3.45.....	120.7	2,320	6.41	170.2	76,200	171.6	230.0	123.5	53.70
4.00.....	121.1	2,320	6.44	168.1	75,300	173.4	232.3	122.6	52.75
4.15.....	121.0	2,316	6.46	166.3	74,500	171.0	229.1	121.6	53.10
4.30.....	120.7	2,320	6.54	167.4	75,000	166.4	223.0	124.1	55.70
Mean..	120.8	2,304	6.13	171.4	76,960	173.4	232.4	117.6	51.37

UNIT NO. 2.¹

Time.	Speed.	Volts.	Actual lift.	Discharge.		Kilo-watts.	Electrical horse-power.	Water horse-power.	Efficiency.
	<i>R. p. m.</i>		<i>Feet.</i>	<i>Sec.-ft.</i>	<i>G. p. m.</i>				<i>Per cent.</i>
1.15.....	120.4	2,300	6.10	170.2	73,200	176.5	233.5	117.5	49.7
1.30.....	121.1	2,338	6.14	171.5	76,800	178.0	238.5	119.3	50.0
1.45.....	123.8	2,310	6.15	171.2	76,700	176.1	236.0	119.2	50.5
2.00.....	121.0	2,310	6.20	167.0	74,800	174.0	233.0	117.3	50.4
2.15.....	123.8	2,320	6.25	169.2	75,800	173.0	231.8	120.0	50.47
Mean..	120.8	2,310	6.15	169.8	76,060	175.5	235.2	118.7	50.47

¹ A mud lump was found in suction basin under one suction pipe.

The test showed an average efficiency at 6-foot lift of 50.55 per cent. At a lift of 6.32 feet and while pumping more than 76,000 gallons per minute the guaranteed efficiency of $52\frac{1}{2}$ per cent was attained.

TESTS OF 12-FOOT WOOD SCREW PUMP, NEW ORLEANS DRAINAGE SYSTEM.

The drainage of New Orleans and the sanitary sewers are separate systems. The area drained amounts to 25,000 acres, or a little more than 39 square miles. The capacity of pumping plants for drainage will eventually be equal to 7.33 inches of run-off removed in 24 hours. The pumping units include eleven 12-foot screw pumps. (See fig. 4.)

Tests were made of one of the 12-foot Wood screw pumps at New Orleans pumping plant No. 1, on November 17, 1916, and January

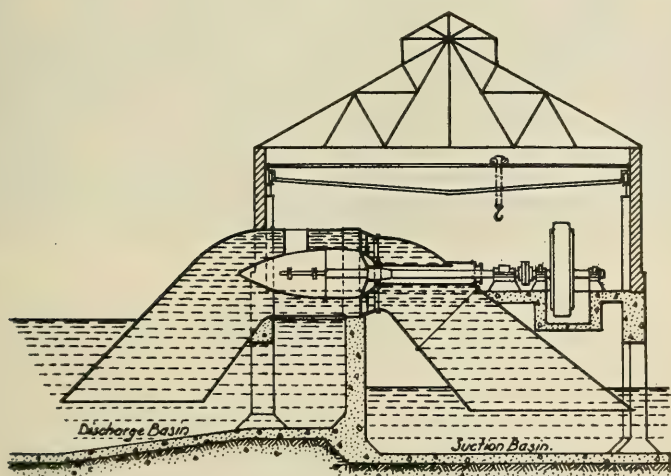


FIG. 4.—Section through 12-foot screw pump, New Orleans drainage pumping plant.

17, 1917. In the test of November 17 the flume was divided into 10 equal areas. As the bottom was V-shaped the width of these sections was greatest at the sides of the flume and least near the middle. Velocities were observed at 0.2, 0.6, and 0.8 depth in each area, and the mean velocity for an area was taken to be the mean of the three velocities observed. The sum of the 10 separate areas multiplied each by its mean velocity gave the total discharge and this divided by the total area gave the mean velocity.

In the test on January 17, 1917, observations were taken of velocity at the same sections as in the previous test but at one-sixth, five-tenths, and five-sixths depth. The mean of three readings was used as the mean velocity of the vertical section, and the total discharge was obtained by summing up the discharges of the separate sections. Table 37 gives the results of the tests.

TABLE 37.—*Tests of 12-foot Wood screw drainage pump at New Orleans pumping station No. 1, Nov. 17, 1917.*

TEST OF NOV. 17, 1916.

No.	Speed.	Quantity pumped.						Lift.	Water horse-power.	Measured electrical horse-power.	Measured E. H. P. $\times 0.94 =$ H. P. input to pump.	Efficiency pump.
		Measured in flume.	Leakage to Broad Street Canal.	Leakage through station.	Correction for storage in canal.	Correction for storage in discharge basin.	Corrected quantity.					
	<i>R.p.m.</i>	<i>Sec.-ft.</i>	<i>Sec.-ft.</i>	<i>Sec.-ft.</i>	<i>Sec.-ft.</i>	<i>Sec.-ft.</i>		<i>Feet.</i>				<i>P. ct.</i>
1...	73.7	457.84	1.74	3.26	21.18	-0.90	482.92	7.59	416.0	585.86	551.0	75.45
2...	74.1	475.73	1.74	3.74	11.45	-4.70	487.96	7.48	414.5	586.77	552.0	75.1
3...	74.1	481.54	1.74	4.35	8.96	-4.34	490.25	7.415	412.5	582.52	547.5	75.3
Av.	74.0	471.70	1.74	3.78	13.20	-3.31	487.11	7.495	413.9	585.03	550.2	75.23

TEST OF JAN. 17, 1917.

1...	75.75	491.35	2.82	2.17	18.25	-0.28	514.31	7.37	430.0	608.5	572.5		75.0
1A.	75.8	488.80	2.82	2.54	15.51	-1.45	508.22	7.41	428.0	610.0	573.5		74.6
2...	76.05	513.10	2.82	3.85	7.85	-3.49	524.13	7.55	448.5	617.0	580.5		77.3
Av.	75.9	497.75	2.82	2.85	13.87	-1.74	515.55	7.44	434.6	611.8	575.5		75.51

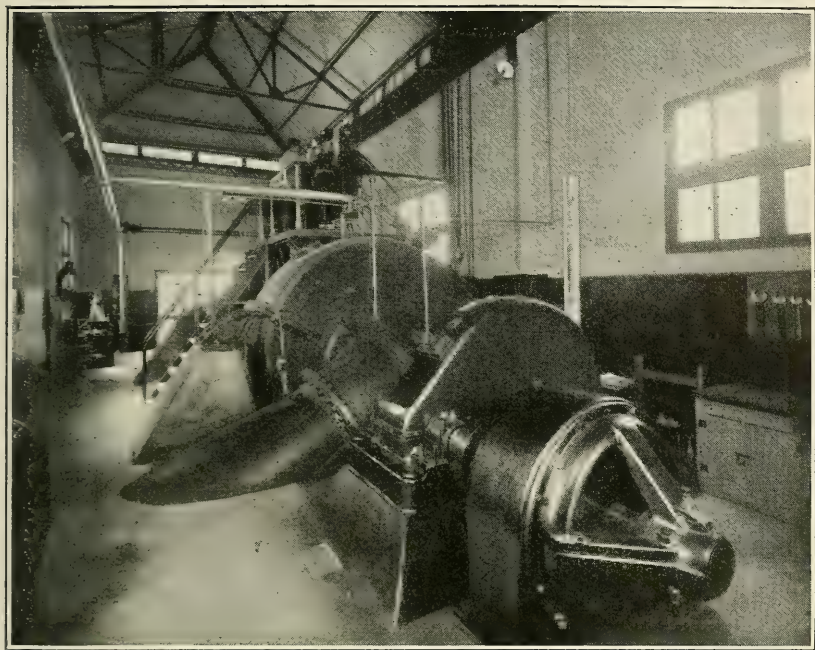
Before each of these tests it was necessary to allow the water to accumulate for about a week, and as the weather was dry the water became rather foul; it carried trash and organic matter which appeared to give off gas.

The lift, or difference of level on suction and discharge sides of pump, was approximately 7.5 feet for all these tests, which is the lift for which the pump was designed. The results obtained from the tests show the efficiency of the pump to be about 75.5 per cent. This is less than was shown by the official test of 1915, when for a lift of 7.15 feet the efficiency of pump was approximately 79 per cent. It is possible that the foulness of the water affected the results to some extent. The efficiency obtained is good in any event.

COST OF OPERATION OF PLANTS.

Information regarding the various pumping plants tested, as well as for some others for which data have been obtained from reliable sources, has been arranged in tabular form (Table 38) and in graphic form (in figs. 5, 6, 7, 8, and 9). All but plants Nos. 19 and 21 have centrifugal pumps. The impellers of the pumps in plants Nos. 8, 9, 10, 11, 12, 20, and 22 (see Table 38) are a combination of the screw and centrifugal principles. Nos. 19 and 21 are screw pumps.

Plants Nos. 1, 2, and 3 are medium-grade steam plants having slide valve noncondensing engines. Plants Nos. 4 and 5 have Corliss noncondensing engines. The former was not tested under the most favorable conditions, while the latter was; No. 5 has a much more elaborate pump than No. 4. Plant No. 6 has a cross-



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INTERIOR AND EXTERIOR VIEWS OF PUMPING PLANT, LITTLE WOODS TRACT,
NEW ORLEANS, LA.

compound condensing Corliss engine. Plant No. 7 has a compound condensing poppet-valve engine using superheated steam. Plants Nos. 8, 9, 10, 11, and 12 are alike in having internal-combustion engines. No. 9 uses kerosene as fuel, while the others may use distillate or kerosene. They are all 4-cycle engines. Plants Nos. 13

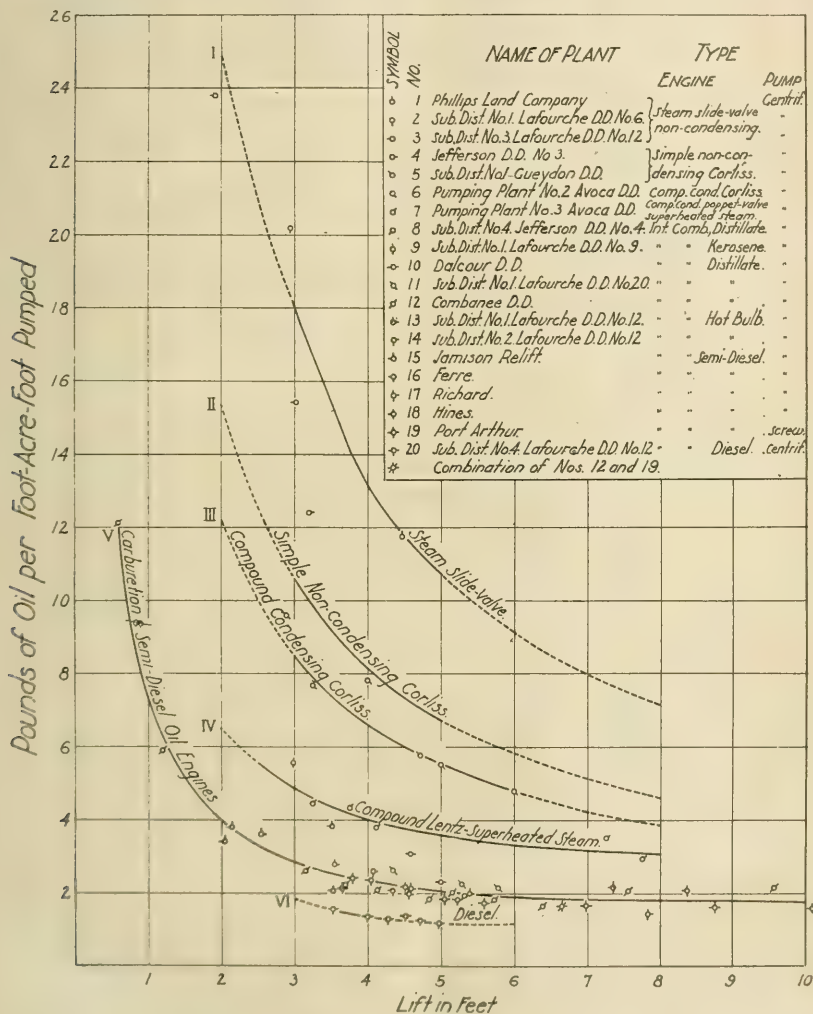


FIG. 5.—Pounds of oil required by different types of engines to pump against various lifts.

and 14 have hot-bulb ignition and operate on the 4-stroke cycle; they use a fairly low grade of fuel oil. Plants Nos. 15, 16, 17, 18, and 19 have 2-cycle oil engines with hot-bulb ignition. Plant No. 20 has 2-cycle Diesel engines using a low grade of fuel oil. Plants Nos. 21 and 22 are electrically driven.

TABLE 38.—Costs of operating drainage pumping plants of various types in Louisiana, South Carolina, and Texas (interest and depreciation not considered).

No.	Name of plant.	State.	Area drained.	Plant capacity.				Area from which plant will remove 1.25 inches per day. ²	Assumed cost of oil per gallon.	Yearly cost of operation.					Yearly cost per acre. ¹	
				Basis 10 second-foot nozzle velocity.		From test at 5-foot lift.				Fuel to start, lubricating and oil, and supplies.	Total fuel and supplies.	Labor.	Total yearly cost of operation.	Total fuel and supplies.	Total fuel, supplies, and labor.	
				Sec.-ft. per day.	Acre-in. per day.	Sec.-ft. per day.	Acre-in. per day.									
1	Phillips Land Co.	Louisiana	2,500	102.1	0.97	1.03	2,060	3.5	\$1,288	\$1,609	\$1,320	\$2,929	\$0.78	\$1.42		
2	Subdistrict No. 1, Lafourche drainage district No. 6.	do.	1,880	62.8	.80	.66	990	3.5	617	772	1,320	2,092	.78	2.11		
3	Subdistrict No. 3, Lafourche drainage district No. 12.	do.	2,250	98.2	1.04	.83	1,480	3.5	924	1,155	1,320	2,475	.78	1.67		
4	Jefferson drainage district No. 3.	do.	5,000	251.4	1.20	1.13	4,530	3.5	1,775	2,220	1,740	3,960	.49	.87		
5	Subdistrict No. 1, Gueydan drainage district.	do.	7,500	318.0	1.01	1.16	6,950	3.5	2,725	3,405	1,740	5,145	.49	.74		
6	Subdistrict No. 2, Avoca drainage district.	do.	4,350	125.7	.69	.70	2,420	3.5	774	968	2,220	3,188	.40	1.32		
7	Subdistrict No. 3, Avoca drainage district.	do.	11,250	282.7	.60	.54	4,870	3.5	1,052	1,315	2,220	3,535	.27	.73		
8	Subdistrict No. 4, Jefferson drainage district No. 4.	do.	1,800	98.2	1.30	1.20	1,730	9.0	540	675	1,500	2,175	.39	1.26		
9	Subdistrict No. 1, Lafourche drainage district No. 9.	do.	1,760	98.2	1.33	.52	747	9.0	233	291	1,500	1,791	.39	2.40		
10	Dalour drainage district No. 1.	do.	4,650	141.4	1.36	1.86	3,650	9.0	1,140	1,426	1,500	2,926	.39	.80		
11	Subdistrict No. 1, Lafourche drainage district No. 20.	do.	2,460	80.5	.98	.97	1,512	9.0	472	590	1,500	2,080	.39	1.38		
12	Comabee drainage district.	South Carolina	1,950	62.8	1.79	1.68	1,123	6.5	252	315	1,500	1,815	.28	1.61		
13	Subdistrict No. 1, Lafourche drainage district No. 12.	Louisiana	835	62.8	1.79	1.68	1,123	6.5	252	315	1,500	1,815	.28	1.61		

	do	940	62.8	1.39	3 42.0	1.06	800	6.5	179	45	224	1,500	1,721	.28	2.16
14	Subdistrict No. 2, 1a fourche drainage district.														
	Louisiana Irrigation & Mill Co. ³														
15	Jackson relief		141.4		71.4		1,350	6.5	302	76	378	1,500	1,878	.28	1.30
16	Porto relief		62.8		81.7		1,013	6.5	362	90	452	1,500	1,932	.28	1.21
17	Richard relief		62.8		120.0		2,296	6.5	512	128	640	1,500	2,140	.28	1.04
18	Hew's relief		31.4		45.6		870	6.5	195	49	244	1,500	1,744	.28	2.01
19	Port Arthur		2,175		281.6		5,300	6.5	1,200	300	1,500	1,500	3,000	.28	.36
20	Subdistrict No. 4, La-fourche drainage district No. 12.		4,240	1.41	243.0	1.37	4,630	3.5	334	83	417	1,500	1,917	.09	.41
21	Station No. 1, New Orleans														
22	Little Woods tract		6,943	1.00	364.0	1.25	6,940								

³ Low-lift irrigation plants.⁴ Woods in pump; see test.⁵ Plant incomplete.¹ Based on acreage from which plant will remove 1.25 inches in 24 hours.² Quantities from tests.

Plant capacity was rated on a velocity of 10 feet per second at the discharge flange of pump. The capacities of the various plants as shown by the test are also included. The capacity of plant in acres drained was next computed on the basis of 1.25 inch removed in 24 hours.

In selecting engines a limit is set by the size of engines of certain types. Slide-valve steam engines may be had in almost any size or capacity, while Corliss engines are not made in small sizes. It would therefore be impracticable to decide to use a Corliss engine on a proposition so small as to demand special design.

Distillate and oil engines of medium grade are not made by some firms in sizes above 100 to 125 horsepower. To use an internal-combustion engine in a pumping plant of large capacity with correspondingly large units would mean the selection of a Diesel or a semi-Diesel engine, both high-grade engines, costing considerable more per horsepower than the medium-grade engines using distillate.

The original costs of pumping plants and the years they were purchased are shown in Table 39. In using the data contained in this table, however, it must be borne in mind that prices of all materials and equipment of pumping plants have advanced materially. The average plant would probably now (1920) cost as much as 75 to 100 per cent more than before the war.

TABLE 39.—*Costs of pumping plants.*

Name of plant.	Acres.	Cost.	Cost per acre.	Year constructed.
Phillips Land Co.	2,500	\$15,000	\$6.00	1911
Subdistrict No. 1, Lafourche drainage district No. 6.	1,880	10,000	5.32	1912
Subdistrict No. 3, Lafourche drainage district No. 12.	2,250	13,500	6.00	1910
Jefferson drainage district No. 3.	5,000	28,000	5.60	1912
Subdistrict No. 1, Gueydan drainage district.	7,500	40,000	5.32	1912
Subdistrict No. 2, Avoca drainage district.	4,350	34,000	7.81	1911
Subdistrict No. 3, Avoca drainage district.	11,250	73,000	6.48	1913
Subdistrict No. 4, Jefferson drainage district No. 4.	1,800	18,000	10.00	1915
Fayport subdistrict No. 1, Lafourche drainage district No. 9.	2,000	14,000	7.00	1913
Dalcour drainage district.	650	10,000	¹ 15.40	1913
Subdistrict No. 1 Lafourche drainage district No. 12.	835	10,500	12.57	1915
Subdistrict No. 2 Lafourche drainage district No. 12.	940	12,500	13.30	1915
Subdistrict No. 4 Lafourche drainage district No. 12.	4,240	31,500	7.42	1913
Little Woods tract.	6,943	37,500	5.39	1913
Port Arthur.	5,720	54,290	² 9.50	1918
Ferre relief.		20,000		1918
Richhard relief.		15,000		1918
Hine's relief.		8,000		1918

¹ Acreage will be considerably increased later.

² Plant costs more than it would for an agricultural proposition, as two units must lift water 11 feet in occasion demands it.

GRAPHIC SUMMARY.

Figure 5 shows the pounds of oil per foot-acre-foot of water pumped, plotted against the lift in feet. The several curves represent different types of plant. While, in some instances the data were sufficient to define the curve accurately, in others the exact definition was a matter of judgment. The amount of fuel shown is

for normal plant operations and does not include the 25 per cent allowance for starting and lubricating oils. The accuracy of the work is limited by the amount of data available.

It will be noted that curve II does not pass through the point plotted for Jefferson drainage district No. 3 nor through point for subdistrict No. 1, Gueydan drainage district, but is drawn between them to give probable results for an average plant of this type. It must be remembered that the test of the former plant showed greatly unbalanced quantities passing through the two suction pipes. The engines are rather large for the pumps, and this doubtless has a material effect on economy. On the other hand, the Gueydan pumps are volute pumps of much more elaborate design than the drainage pumps of Jefferson drainage district No. 3. The pumps were large and the velocities of water through them comparatively slow; all these factors made for lower fuel rate.

Figure 6 shows the cost per year of pumping 29 acre-inches against various lifts, as obtained from the curves of figure 5. For the average drainage proposition discussed in this report the lift for the first two or three years is approximately 3 feet; later, when a part of the humus disappears and deeper drainage is desired, the lift is increased to 5 feet or more. The general range of lift was from 2 to 8 feet.

In all the tests recorded oil was used as fuel. In order to make a comparison of cost it is necessary to consider the kind of oil used in the different plants. The steam plants and the Diesel-engine plant No. 20 (fig. 5), either used or could use Mexican crude or some low grade of fuel oil. Prices of fuel oil have fluctuated considerably during the last seven years. During 1919 and 1920 the price of oil delivered at New Orleans has ranged from about 75 cents to \$3.50 per barrel. The prices of distillates and kerosene have shown variations that make it impossible to arrive at a probable cost for the future because of the great instability of prices.

The average price of the lower grade of fuel oil delivered at the pumping plant for the years 1912-1917 was about \$1.10 per barrel of 42 gallons. For hot-bulb engines of the semi-Diesel type a higher grade of crude oil is required. The price for this oil delivered at pumping plants for the same period ranged from \$1.40 to \$1.80, with the average about \$1.60.

Some internal-combustion engines, such as those in plants No. 8 and No. 10, are supposed to use a distillate of low grade, costing about the same as the fuel oil used in the semi-Diesel engines. In some instances distillate has been mixed with kerosene to make a more satisfactory fuel. Plants Nos. 8 and 10 may be operated in this way. Plant No. 9 uses kerosene. The cost of distillate deliv-

ered at pumping plants in the period 1912-1917 has been about 4 cents per gallon or \$1.68 per barrel, while kerosene has cost about $7\frac{1}{2}$ cents per gallon or \$3.15 per barrel. Possibly kerosene in tank-car lots was purchased at a lower figure, but many plants have

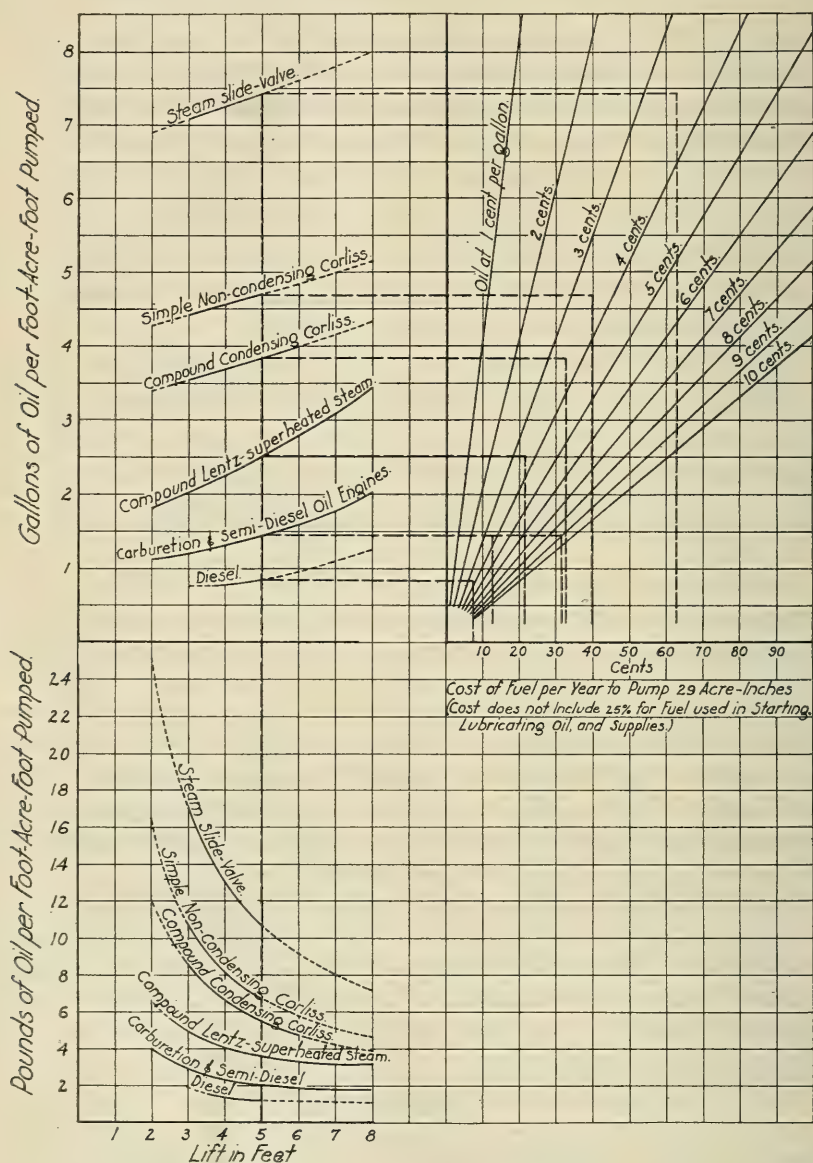


FIG. 6.—Cost of fuel oil to pump 29 acre-inches.

limited storage capacity and fuel is purchased in smaller quantities.

The cost of fuel has been assumed to be as shown in Table 40.

TABLE 40.

	Per gallon.	Per barrel of 42 gallons.
Low-grade fuel oil.....	\$0.035	\$1.47
Better grade fuel oil (distillate).....	.065	2.73
Kerosene.....	.090	3.78

An allowance has been made for fuel used in starting, lubricating oil, and supplies, amounting to 25 per cent of the assumed cost of fuel oil. While the prices of fuel oils are so unstable these assumed prices

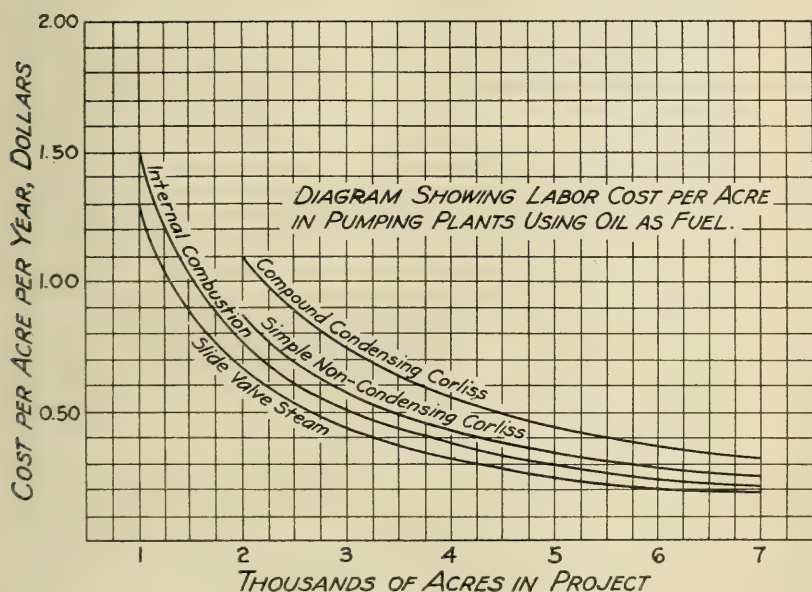


FIG. 7.—Labor cost per acre in pumping plants using oil as fuel.

are probably as good as any others. Figure 6 has been arranged with oil prices varying from 1 cent to 10 cents per gallon, so that corrections may easily be made for changes in fuel costs.

Figure 7 shows the labor costs per acre per year for pumping plants. The basis on which they were computed is shown in Table 41.

TABLE 41.

Type of plant.	Engineers, per month.	Assistants, per month.	Total, per month.
Simple noncondensing steam.....	\$70.00	\$40.00	\$110.00
Simple Corliss.....	85.00	60.00	145.00
Compound condensing Corliss.....	110.00	75.00	185.00
Internal combustion.....	75.00	50.00	125.00
Electric.....	75.00	50.00	125.00

The above wages are approximately 25 per cent greater than those paid in 1917. In considering the above table, it must be remembered that the plant operator is usually furnished a house and garden and is able to engage in agriculture on a small scale. In some cases he is able to do considerable repairing of farm machinery in addition to his duties at the pumping plant. Wages therefore are considerably lower than those paid in commercial plants, where full time is required.

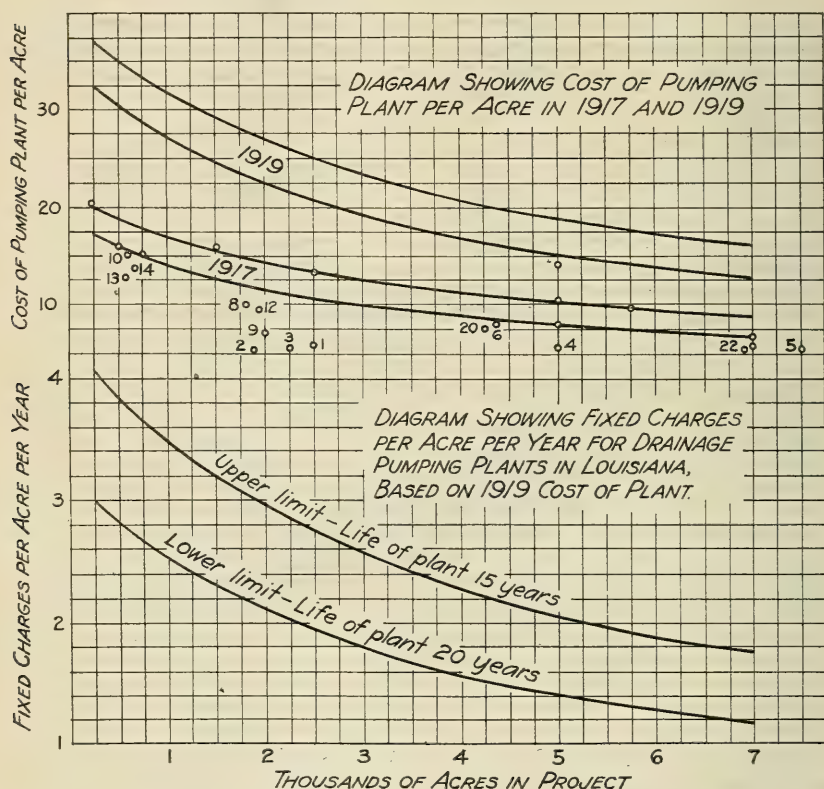


FIG. 8.—Cost of pumping plants and fixed charges per acre per year.

The actual costs of some of the plants tested are shown in figure 8. The costs for 1919 were obtained by increasing the 1917 price by 88 per cent, which is the average increase in the cost of material and labor. The two lines for each year represent approximately the upper and lower limits of cost, depending upon the type of plant constructed.

The upper limit of fixed charges per acre per year was obtained by taking the interest on the upper limit of cost of pumping plant per acre for 1919 computed at 6 per cent and adding an annuity on a basis of 4 per cent that will replace the plant in 15 years; the lower limit was obtained by taking the interest on the lower limit of cost per acre for

1919 and adding an annuity on a basis of 4 per cent and that will replace the plant in 20 years, amounting to \$33.58 per \$1,000. The life of a pumping plant depends largely on the grade of machinery used and the care it receives. It is believed that the limits of 15 to 20 years

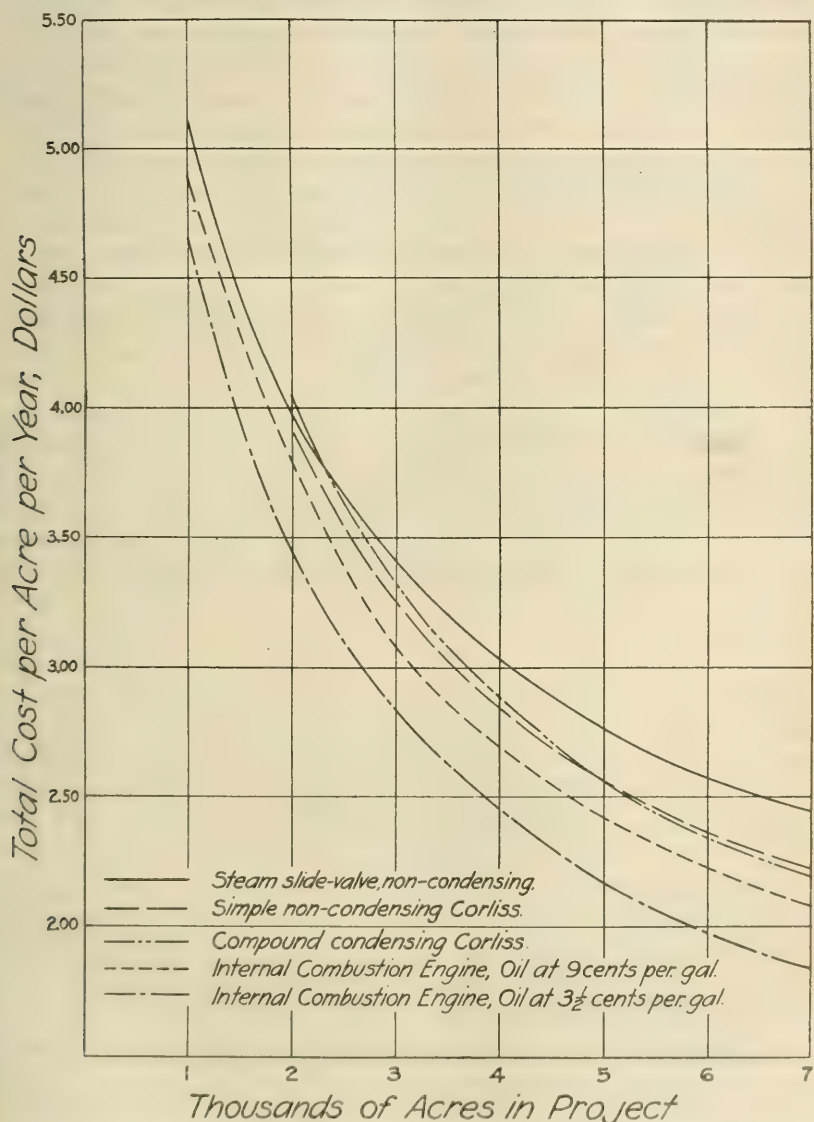


FIG. 9. —Total cost per acre per year, of drainage pumping plants of various types in Louisiana, including fuel, supplies, labor, and fixed charges.

will cover most cases, although occasionally a pumping plant will not last more than 10 years, while another under favorable circumstances may last 25 years.

Figure 9 indicates the total cost per acre per year, including fuel, supplies, labor, and fixed charges, of pumping plants of various types in the southern prairie region, where an average of 29 inches of depth of water is pumped annually. The cost of the fuel, as assumed, is given in Table 36; labor charges are shown in figure 8; the fixed charges are assumed as the mean of the fixed charges for the year 1919, as shown in figure 8. It will be noted that the cost decreases as the size of the project increases. The average cost per acre of operating a pumping plant for a project of 3,000 acres is approximately \$1 per acre per year more than for a project of 7,000 acres. This is an incentive toward reclaiming lands by pumping in fairly large units.

From figure 9 it will also be seen that with the assumptions made the most expensive plants for projects with acreage 2,400 or more is the steam plant with slide-valve engine. There is little choice between the simple Corliss engine and the compound condensing type, the former having a slight advantage for projects of more than 5,000 acres and the latter being a little cheaper for projects between 2,000 and 5,000 acres. The cheapest plant of all has internal-combustion engines, and the difference in various plants will depend quite largely on the price paid for fuel.

While the above analysis is for a set of conditions that are assumed as typical, different conditions will modify the results, and corrections in computations may be quickly made to fit special conditions.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1068

Contribution from the Office of Farm Management
and Farm Economics
G. W. FORSTER, Acting Chief



Washington, D. C.

May 12, 1922

FARM OWNERSHIP AND TENANCY IN THE BLACK PRAIRIE OF TEXAS.

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(Division of Land Economics, L. C. Gray, Economist in Charge.)

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PURPOSE AND SCOPE OF INVESTIGATION.¹

The Black Land Prairie of Texas has long been regarded by students of American tenure problems as a region of special interest. The percentage of tenantry is high, and the development of the tenant system has been unusually rapid. Since the region was but sparsely settled at the close of the Civil War, and since there has never been a high percentage of negro farm operators in the region—in 1926 but 15.9 per cent—tenancy in the Black Land is not attributable to the historical reasons which serve to explain, in the main, the prevalence of tenancy in other sections of the South. However, the one-crop system, with cotton as the basis, prevails here as elsewhere in the South where there is also a high percentage of negro tenantry.

The region is of special interest, furthermore, because of the social and political unrest arising from its tenure problems, which at times has been a major factor in politics in the State and attracted national attention. Shortly after 1900 tenure conditions gave rise to the payment of a bonus above the customary one-third grain and one-fourth cotton share rent—the share paid since early renting days in the

¹ Acknowledgment for helpful cooperation in planning field work and collecting data is given to Mr. C. O. Brannen, of the Office of Farm Management and Farm Economics; to members of the faculties of the Texas Agricultural and Mechanical College and the Texas State University for valuable suggestions as to plans for field work; and to Miss M. I. Herb, who assisted in the tabulation of the data.

State. The bonus system aroused violent antagonism among renters, culminating in the organization of the Renters' Union of America in 1911. By 1914 the situation had become so acute that the United States Industrial Relations Commission held investigations on the land problem in the region, and the bonus problem became the main issue of the Texas gubernatorial campaign of that year, resulting in the election of the candidate advocating an antibonus law. This

law, discussed more fully later, was passed the year following the campaign. It is an interesting and unprecedented experiment in land legislation in this country.

There are four districts in Texas known locally as "black land prairies." The area covered in this study comprises 19 counties² lying wholly or in large part in the main Black Land Prairie—sometimes known as the "Black Waxy Belt." (Fig. 1.) These 19 counties, designated throughout this bulletin as *the black land*, are similar in agricultural, economic, and social conditions.³

The study is based mainly on data taken

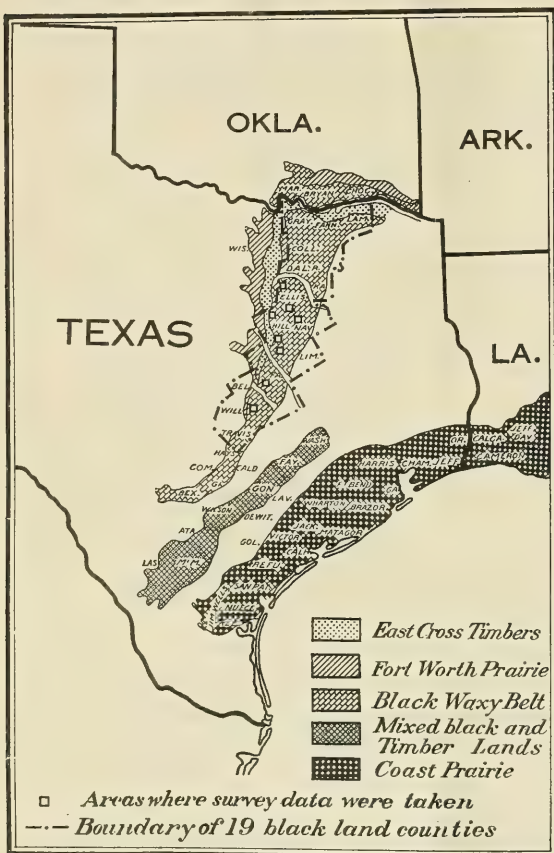


FIG. 1.—Map of black land prairies of Texas, showing locations where data were taken for this study.

in 6 representative counties⁴ from 368 farm operators, particular pains being taken to avoid any selection of the men to be interviewed,

² These counties are Bell, Collin, Dallas, Delta, Ellis, Falls, Fannin, Grayson, Hill, Hunt, Kaufman, Lamar, Limestone, McLennan, Milam, Navarro, Rockwall, Travis, and Williamson.

³ The portion of the Black Land Prairie lying southwest of Travis County is not included in the study because its system of agriculture and economic and social conditions are different from those in the 19 counties included in the study.

⁴ Dallas, Ellis, Hill, McLennan, Bell, and Williamson; also a few schedules were taken in Johnson and Navarro Counties. (See map, Fig. 1.)

because it was desired to get a true cross-sectional view of tenure in the area.

The Black Land Prairie is high, gently rolling, and well drained, with numerous streams crossing it from west to east. Along the larger streams are wide, flat bottom lands, many of which are not yet cleared of their heavy growths of timber, and which are subject to disastrous overflows when in crops and not protected by levees. The outstanding topographical feature of the area is the "White Rock Escarpment," extending near the western edge from Sherman to Austin. This bluff is more or less pronounced, rising 300 feet above the plain at its highest point in Dallas County, and much of the untillable land of the black land is adjacent to it.⁵

An authority on the soils of this region has described them as follows:⁶

The prairies are characterized by black or dark-colored soils derived from a substructure of calcareous marl or chalky limestones, and are the most fertile of the whole Trans-Mississippi region. This fact, together with the comparative scarcity of untillable land, enables it to support the densest agricultural population of Texas.

The black land soils are very sticky when plowed wet and very hard and cloddy when plowed too dry, but the clods readily break up when rains fall upon them. During droughts the soil is apt to crack if not frequently cultivated, but when cultivated enough to keep cracks from forming, it ranks among the most drought-resistant soils in the State.

The climate of the black land is almost ideally suited to cotton growing, and, on account of the relative importance of this crop, which is highly susceptible to cold, to wet weather, and to drought, unusual weather conditions radically affect the income of the average black-land farmer.

SUMMARY OF FINDINGS.

Tenancy increased most rapidly in this area when the character of farming was changing from stock raising to crop growing.

The greatest increase in land values occurred in the past two decades, during which time there was relatively no increase in the number of operators in the black land. This rapid increase in land values was primarily the result of an increase in the productive capacity of the land, measured in terms of dollars.

No evidence was found of increasing concentration of ownership of land in the area.

⁵ See Part VII, 21st Annual Report of the U. S. Geological Survey, p. 68; also University of Texas Bulletin No. 1818, *The Geology of Dallas County*, pp. 9-10.

⁶ R. T. Hill, 21st Annual Report of the U. S. Geological Survey, Part VII, p. 60.

The net return to the owners of rented land was 5.9 per cent on capital invested. Aside from this return, increases in land values, for all land bought in the black land by the operators interviewed, equaled a net compound annual interest of from 8 to 9 per cent on the original investment.

On the basis of the average net accumulation of wealth in 1919, and the average value of farms operated, it would require the average share tenant interviewed approximately 28 years to pay for the farm he operated.

The different tenure stages function not only as stepping-stones in tenure progress but they function also as selective agencies, tending to keep the operators of least ability in the lower stages.

The ability of different operators to accumulate wealth varied widely. Fourteen operators (or 3.8 per cent of all interviewed) together saved annually as much as 238 other operators (or 64.8 per cent of all interviewed) who ranked among the least thrifty.

The group of operators who accumulated wealth most rapidly included those who had been most consistent in the application of their time to operating farms, had the most diversification of farm enterprises, raised the largest amounts of family food on the farm, and moved least frequently from farm to farm.

Comparative data on school records of children of owners and tenants show the record for children of owners to be much better than that of children of tenants.

THE DEVELOPMENT OF TENURE PROBLEMS IN THE BLACK LAND.

EXTENT AND GROWTH OF TENANCY IN THE AREA.

It will be noted from Table 1 that there have been two well-defined periods in the growth of tenancy in the black land since 1880, the first 20 years being a period of very rapid increase in tenancy, and the last 20 years marked by a decided falling off in the rate of increase. During the first period the percentage of all farms that were operated by tenants increased from 41.8 to 61.5, an increase of 19.7, while during the last period the increase was from 61.5 to 66.1, an increase of only 4.6 per cent.

Because of its bearing on discussions to follow, it is significant to note the fact that of the total increase in number of farms, or farm operators, from 1880 to 1920, 88.4 per cent took place during the first 20 years, the years when tenancy was increasing most rapidly.

By 1920, 66.1 per cent of all farms in the black land, or nearly two out of every three, were operated by tenants. Moreover, tenants operated 64 per cent of the total area in farms in the black land, and the value of the land and buildings of the farms which they operated was 60 per cent of the total farm value in the area.

Of the 368 farms surveyed in this study, 70.4 per cent were operated by tenants. Including the land rented by owners who rented additional land (*owners additional*), 68.5 per cent of the land operated by all of these farmers was rented land, the value of which was 63.7 per cent of the total value of all land and buildings.

In comparison with most other sections of the country the growth of tenancy in the black land has been very rapid. Since 1880 the total percentage increase in tenantry for the black land has been 24.3 per cent, for the State of Texas 15.7 per cent, and for the United States 12.5 per cent.

TABLE 1.—*Increase in number of farms operated by tenants and owners in the black land, as compared with the State and the United States, by decades, since 1880.*¹

Census year.	Total number of farms in black land operated by—		Per cent of all farms operated by tenants.		
	Owners and managers.	Tenants.	In black land.	In State of Texas.	In the United States.
1880.....	26,703	19,155	41.8	37.6	25.6
1890.....	29,005	31,805	52.3	41.9	28.4
1900.....	35,871	57,270	61.5	49.7	35.3
1910.....	33,018	60,704	64.8	52.6	37.0
1920.....	31,924	62,245	66.1	53.3	38.1

¹ Computed from U. S. Census publications.

Evidently, therefore, conditions in the black land have been more conducive to a rapid increase in tenantry than in other sections of the country, and it is the discussion of this growth, its causes, and its effects, that has aroused nation-wide interest in the land problem of this area.

UTILIZATION OF LAND IN RELATION TO TENURE.

Agricultural development had scarcely begun in the black land by 1860, as is noted from Table 2. At that time the number of farm operators in the black land was only 7.5 per cent of the number in 1920; and only 4.3 per cent of the total area in the 19 counties was then in improved farm land, as compared with 51.1 per cent in 1920.

The great increase in the number of farmers has been taken care of mainly by a corresponding increase in improved land rather than by an increase in total land in farms. The number of farms in 1920 was 13.4 times as many as the number in 1860, but the total acreage in farms was only 2.2 times as much in 1920 as in 1860. The total improved acreage in farms, however, in 1920 was 14.1 times the amount of all improved land in 1860—a relative expansion

slightly larger than the relative increase in number of farm operators. Since 1880 the total area planted to all crops has increased about 3.5 times.

The decades of 1870 to 1880 and 1890 to 1900 were the two outstanding periods in the increase of the number of farm operators. If data on tenancy were available for the former decade, these two decades undoubtedly would also be shown as the outstanding periods as regards increase of tenants in the area. The increase in number of tenants in the single decade from 1890 to 1900 was 59.1 per cent of the total increase in tenants from 1880 to 1920. Therefore, a more intensified use of farm land has been the principal means whereby the great increase in farm operators has been met; and this use has taken the form of crop growing, so that in 1920, 89.6 per cent of all improved land was in some kind of crops.

TABLE 2.—*Utilization of land for farming purposes in the black land, by decades, since 1860.*¹

Census year.	Total number of farms.	Total number of acres in farms.	Per cent of area of black land in farms.	Per cent of farm land improved.	Per cent of farm land in crops.
1860.....	7,036	3,963,348	37.4	11.7	(²)
1870.....	14,403	3,251,056	30.7	20.8	(²)
1880.....	45,858	6,104,472	57.7	46.7	27.3
1890.....	60,513	6,920,337	65.4	³ 68.5	39.4
1900.....	93,141	8,552,277	80.8	64.4	54.1
1910.....	93,723	9,018,607	85.2	68.6	56.6
1920.....	94,169	8,535,123.	80.6	76.3	65.5

¹ Computed from U. S. Census data. Data for 1860 slightly incorrect on account of county boundary changes.

² Data not available for these dates.

³ This per cent is increased because of a change in the definition of improved land.

CHANGES IN SIZE AND TYPE OF FARMS AS RELATED TO TENURE GROWTH.

Practically all of the good agricultural land of the black land was granted to its original owners in holdings that were considerably larger than the average size of holding at present. The maximum amount of land ordinarily granted to a married man when Texas was an independent nation was a league and a labor (4,605 acres), and 640 acres after it became a State in the Union. The average size of holdings in the area was probably increased rather than decreased by the depression following the Civil War, which caused land values to decline and stock raising to continue as the principal farm enterprise until 1870. By 1860 practically all good available agricultural land was patented in holdings of an average size much larger than the present average size of farms.

After 1870, when great numbers of immigrants began to come into the black land, changing the system of farming to crop growing, many of the original owners of large tracts chose to retain owner-

ship, but to break up their holdings and rent them, because of the large returns from crop growing as compared with grazing.

The inflow of immigrants during the decade from 1870 to 1880 greatly influenced the agriculture of the region, reducing stock raising to a secondary place in farm enterprises, decreasing the average size of the farm to about one-fifth of the average for 1860, and developing tenancy until 41.8 per cent of all farms were operated by tenants in 1880 (see Tables 1 and 2).

The size of the farm continued to decrease during the two decades following 1880, although this decrease was much less than the decrease prior to that date. Cotton growing had reached and continued to hold a dominant place among farm enterprises, though checked in its development by the extremely low prices prevailing during the decade from 1890 to 1900.

TABLE 3.—*Changes in the average size of farms and in system of farming since 1860, for black land farms.*¹

Census year.	Acres in farms.	Im- proved acres in farms.	Acres in crops.	Per cent of crop acres in cotton.	Units of live stock on farms. ²
1860.....	563.3	65.8	(3)	(3)	121
1870.....	225.7	47.0	(3)	(3)	51
1880.....	133.1	62.1	36.4	40.9	20
1890.....	114.4	78.4	45.1	48.7	18
1900.....	91.8	59.1	49.7	47.8	12
1910.....	96.2	66.0	54.5	61.7	10
1920.....	90.6	69.2	59.3	59.7	9

¹ County changes between 1860 and 1870 affect data somewhat, though not materially.

² A live-stock unit as used here is equal to 1 grown horse, 1 grown cow, 7 hogs, or 7 sheep or goats. There is some discrepancy in these figures for some dates, since some census figures do not distinguish between young and mature stock. Number averaged by all farms.

³ Figures not available for these dates.

With better cotton prices prevailing after 1900, cotton growing rapidly encroached on all other farm enterprises, until, by 1920, 59.7 per cent of all crop land was in cotton. In fact, on many farms practically all agricultural efforts were expended directly or indirectly on cotton growing. During the decade from 1900 to 1910, the average size of the farm showed the first increase since 1860, although in the decade just past it has again shown a decrease.⁷

It is evident, therefore, that the most rapid growth of tenancy has taken place when the greatest increase of operators occurred, and that this has been closely associated with the breaking up of the stock-raising industry and the larger farms.

⁷ The limiting factor to the introduction of improved machinery in cotton growing is the picking, no practical picking machine having been developed as yet. The average farmer, without the latest improved tilling, planting, and cultivating machines, can grow more cotton than he and his family can pick. The unusually large cotton farms of the black-land farmer are operated by using improved machinery for growing the crop and by importing a picking force of negroes and Mexicans, the former coming from cities and the latter from Mexico and counties near the border.

Table 4, giving farms classified by size, shows that since 1860 there has been a rapid and uninterrupted increase in the number of farms of the size groups of 20 to 50 acres, 50 to 100 acres, and 100 to 500 acres. On the whole, there was an increase in the number of farms in the size groups above 500 acres until 1890, since which date there has been a decrease.

From the standpoint of this discussion it is unfortunate that the census tabulations for decades prior to 1900 do not show the farms of 100 to 500 acres broken into three groups, as has been done since 1900, for 96 per cent of the increase in the total number of farms of from 100 to 500 acres, between 1900 and 1920, was owing to increase in the number of farms of 100 to 175 acres in size; that is, to an increase in the number of farms in the group including sizes nearest the average for the black land.

TABLE 4.—*Number of farms in different size-groups in the black land, by decades, since 1860.*¹

Census year.	Under 20 acres.	20 to 50 acres.	50 to 100 acres.	100 to 500 acres.	500 to 1,000 acres.	1,000 acres and above.
1860.....	1,246	2,884	1,905	1,280	59	7
1870.....	3,634	5,960	3,394	1,380	27	2
1880.....	4,813	13,859	10,190	15,406	1,106	484
1890.....	3,317	20,868	16,420	13,244	1,140	524
1900.....	² 5,732	29,496	31,451	25,263	802	397
1910.....	² 5,087	23,002	34,875	29,712	710	336
1920.....	6,210	24,496	33,497	29,056	662	239

¹ Computed from U. S. Census data.

² These increases are largely the results of a change in the definition of "farm."

The possible increase in tenancy that would follow the breaking up of all farms of 500 acres or more, assuming that the ownership of these farms did not change after breaking up, is shown in Table 5. It will be noted that the greatest number of tenant farms would have resulted from the breaking up of farms of 500 acres or more during the decade 1890 to 1900, when the greatest increase in tenant farms occurred (59.1 per cent of the total increase since 1880). Furthermore, it will be noted that, as a result of the slackened rate of increase of tenants each decade since 1890, the breaking up of farms of 500 acres or more has possibly played an increasingly important rôle in the growth of tenancy (see Table 5, last column).

Some writers on the tenure of this region have held that large holdings in land were increasing in number and size in the black land and that this was partly the cause of the growth of tenancy. But data on all the land owned by persons owning 200 acres or more taken from the tax rolls of Ellis, Hill, McLennan, and Bell Counties, and summarized in Table 6, do not show that there has been a tendency toward an increase in concentration of ownership in large holdings.

There was a decided tendency toward a decrease in land held in holdings of 1,000 acres or more, the total decrease from 1899 to 1919 being 21.3 per cent of the amount held in 1899. The percentage decrease for all holdings above 500 acres was 8.8. Holdings of from 200 to 500 acres in size, however, showed a slight increase of 6.4 per cent over the amount held in 1899.

Land held by nonresidents of the counties has shown a decidedly greater tendency to decrease in the larger-sized holdings than has all land, the total decrease in land in all nonresident holdings of 200 acres or more decreasing 21.4 per cent since 1899.

TABLE 5.—*Estimated possible increase in black land tenancy resulting from the breaking up of farms of 500 acres or more.*¹

Period.	Total increase in number of tenant farms for decade.	Decrease (–) or increase (+) in number of farms of—		Possible increase in number of tenant farms resulting from change. ²	Per cent that possible increase was of total increase in tenantry. ³
		500 to 1,000 acres.	1,000 acres and above.		
1880-1890.....	12,650	+ 36	+ 40	4,675	45.3
1890-1900.....	25,465	–338	–127	4,489	13.7
1900-1910.....	3,434	– 92	– 31	1,120	32.6
1910-1920.....	1,541	– 48	– 98	1,749	113.5

¹ These data are computed from Census publications.

² This figure was arrived at as follows: Farms of from 500 to 1,000 acres each were assumed to average 750 acres in size; and farms of 1,000 acres or more, 1,250 acres in size. These acreages were multiplied by the increase or decrease in the number of their respective size farms, giving total increase or decrease of acreage in farms above 500 acres. This total acreage was divided by the average size of the farm at the end of the decade, giving the figure in the column above.

³ Preceding column divided by first column of table.

⁴ Decrease.

TABLE 6.—*Extent of concentration of ownership of land in holdings of different sizes in Ellis, Hill, McLennan, and Bell Counties, for different periods.*¹

I. ALL LAND KNOWN AND RENDERED.

Year.	Holdings of 200 acres and over.		Holdings of 500 acres and over.		Holdings of 1,000 acres and over.		Holdings of 200 to 500 acres.	
	Total acres.	Per cent of 1899 acreage.	Total acres.	Per cent of 1899 acreage.	Total acres.	Per cent of 1899 acreage.	Total acres.	Per cent of 1899 acreage.
1919.....	1,507,626	98.1	764,770	91.2	362,147	78.7	742,856	106.4
1914.....	1,541,267	100.3	760,766	90.7	364,641	79.3	780,501	111.8
1909.....	1,537,313	100.0	792,557	94.5	385,005	83.7	744,756	106.7
1904.....	1,584,606	103.1	831,809	99.2	416,287	90.5	752,797	107.9
1899.....	1,536,963	100.0	838,685	100.0	459,975	100.0	698,278	100.0

II. LAND OWNED BY NONRESIDENTS.

1919.....	154,107	78.6	92,981	65.8	47,945	51.6	61,126	111.6
1914.....	182,185	93.0	117,358	83.1	69,591	75.0	64,827	118.4
1909.....	185,914	94.9	118,283	83.8	67,802	73.0	67,631	123.5
1904.....	171,662	87.6	119,240	84.4	65,587	70.7	52,422	96.7
1899.....	195,981	100.0	141,212	100.0	92,828	100.0	54,769	100.0

¹ Data taken from county tax records.

CHANGES OF FARM VALUES IN RELATION TO TENURE.

Agriculture in the black land has passed in 60 years from the pioneering stage of 1860, when the best land was plentiful and relatively cheap, to the well-established system of crop growing of 1920, with all but the very poorest land in use. As one would expect, this change has affected land values more than it has affected equipment values on the average farm.

Land values rose from an average of \$5.57 an acre in 1860 to \$116.47 in 1920, an increase of 20.9 times \$5.57, while during the same time the value of equipment per acre rose from \$3.48 to \$12.56, an increase of only 3.6 times \$3.48 (see Table 7).

The general depression following the Civil War caused both land and equipment values to decline from 1860 to 1870. However, equipment values continued to decline until 1880, owing to the breaking up of the stock-raising industry. There was 1 animal unit for each 4.4 acres of land in farms in 1870 and 1 for each 6.7 acres in 1880.

The striking increase in farm operators between 1890 and 1900, however, did not greatly affect land values, which increased only 38.9 per cent during the decade as compared with an increase of 95.5 per cent for the previous decade and 93.8 per cent for the decade following.

TABLE 7.—Average farm values per acre in the black land, by decades, since 1860.¹

Census year.	Average value of land and buildings per acre.	Average value of equipment per acre.	Average value of machinery per acre.	Average value of live stock per acre.
1860.....	\$5.57	\$3.48	\$0.31	\$3.17
1870.....	5.45	3.13	.28	2.85
1880.....	9.07	2.44	.48	1.96
1890.....	17.73	4.06	.61	3.45
1900.....	24.63	5.10	1.09	4.01
1910.....	47.74	7.41	1.51	5.90
1920.....	116.47	12.56	4.15	8.41

¹ Computed from U. S. Census data.

The increase in land values since 1900 has been 4.8 times as great as the increase during the four decades previous to that date. This phenomenal increase in the value of land occurred in a period when the size of the farm, the system of farming, and the number of farm operators practically remained unchanged.

This great increase in value was largely the result of competition for the purchase of the land's annual use value (present and prospective) without any significant change in the number of operators. This statement is supported by the fact that the bonus system (see p. 13) grew up during the decade from 1900 to 1910, although the

number of farm operators in the 19 black-land counties increased during this decade scarcely one-half of 1 per cent. On the other hand, land in farms increased 5.4 per cent.

That the rapid increase in the value of land in this area was closely related to the trend of the value of the products that were produced on the land is indicated by Figure 2, which shows the movement of land values, and the movement of the values of the corn, small grain, and cotton produced on the land.⁸ In general, the movement of the curves are quite close together after 1890, when the present system of agriculture became fairly well established. Were data on annual land values available the curves would probably move more closely together.

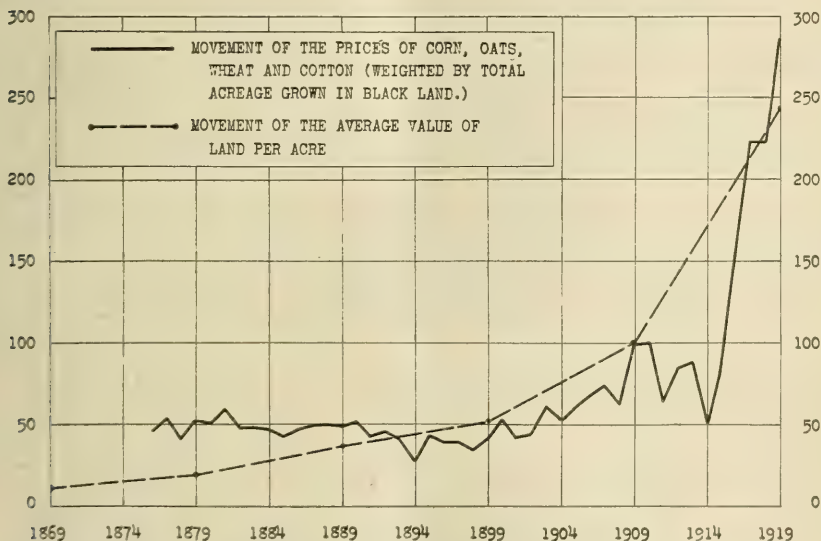


FIG. 2.—Movement of the average value of land per acre and of the prices of the principal products raised on farms, for the black land of Texas.

The rapid increase in land values during the past two decades is, therefore, primarily the results of an increase in the productive power of the land (measured in terms of dollars), which has reflected itself in higher prices for land. However, war-time prices of

⁸ The index figures of the value of the principal crops raised on the land were calculated as follows: The average annual farm prices of corn, oats, wheat, and cotton, as given by Yearbooks of the United States Department of Agriculture, were expressed in price per pound. These prices were weighted by the respective acreage of these crops grown in the black land as reported by each decennial United States Census, the acreages given by each census being used to weight prices for the four years preceding the census year, for the census year, and for the five years following the census year. These weighted figures for the price of each of the four crops were added together for each year, and their sum was the figure from which the index figure, on the value of products raised in the black land for each year, was calculated. The census year 1909 was taken as the base.

cotton have, no doubt, raised land values to levels that prewar prices would not justify, and if cotton prices return permanently to prewar levels, land prices may decline as they did following the Civil War.

LEGAL PHASES OF THE LAND PROBLEM.

The landlord's lien law is designed to protect the landlord against unscrupulous tenants who might try to get out of paying their debts to the landlord. It provides that the landlord has a prior lien, whether contractual or not, on the tenant's crop for advances furnished the tenant to make the crop, for any rent due on the year's crop, and for teams, tools, and feed furnished the tenant by the landlord.

The present homestead exemption law is based on a constitutional provision⁹ and exempts from forced sale a legally designated homestead of 200 acres, regardless of the value of the land and the improvements on it. No lien of any kind on the homestead is valid, except for taxes due on it, for the original purchase price, and for work and material used in putting permanent improvements on the place. Court interpretations of this law have been very rigid, and much opposition to its provisions has developed. However, repeated efforts to repeal or amend it have met with failure.¹⁰

The amount of value exempt at present is unquestionably much larger than was ever intended by those framing the provision in 1875. Two hundred acres of some of the farms surveyed were worth \$60,000, including the improvements on them. Yet, under the present law, every cent of this is exempt from seizure for debt, except as noted, and the land can not be used directly as a basis of credit to the owner. Such conditions are bound to affect the credit situation in the State, making money for legitimate expansion of the farm business expensive and difficult to obtain. Without doubt, a limitation on the value of the exempted homestead would eliminate undesirable results of the present law, without seriously impairing the employment of the principle of homestead exemption as a means of protection from injustice and economic oppression.

There has long been a public sentiment in the State against the ownership of farm land by nonresident aliens and by nonfarming corporations. Land can be acquired by such agencies only by foreclosure, for debt on the land, or as a settlement for other debts, and for judgment granted to the alien or corporation. But this land

⁹ See Article XVI, Secs. 50 and 51 of State Constitution, and for the law see The Complete Statutes of Texas of 1920, pp. 612-614.

¹⁰ An amendment to the constitutional provision for the exemption of the homestead was submitted to the voters of the State for ratification in 1919, but failed to pass by a small majority, although it had the support of the Farmers' Union officials, the Texas Farmers' Congress, the Federal Land Bank at Houston, officers of the Extension Department of the State A. and M. College, and most of the daily papers of the State.

must be disposed of within specified periods of time after possession is secured.¹¹

The antibonus law, as has been noted, was the result of agitation against the bonus system.¹²

This law makes it illegal to contract for or collect a rent *in excess of the value of one-third of the grain and one-fourth of the cotton raised on the land* where the landlord furnishes only land and improvements, and a rent *in excess of one-half of the crops* where the landlord furnishes land, improvements, and equipment. A tenant who is charged a rent in excess of this can collect from the landlord by legal proceedings double the amount of the rent, and, furthermore, the landlord loses his right to the landlord's prior lien.

Strict enforcement of this law would, no doubt, have far-reaching social effects in areas where the specified share rent yields a very low return on the value of the land, since it would tend to keep land values much lower than they would otherwise be. A legally prescribed and unvarying rent must be justified on social and not on economic grounds, for it does not provide for adjustment to meet changes in economic conditions that affect the amount of rent that equitably may be asked for the use of the land.

The factors of production have been classified as *land, equipment, and labor*—the human element of labor and management.¹³ In the black land the landlord furnishes only land, when renting his land on a one-third and one-fourth share basis, and the tenant furnishes the other two factors. The reward to land is rent, and the reward to the other factors is usually spoken of as interest on equipment and capital and labor income.

Variations in the values of the landlord's and tenant's respective contributions toward the operation of the farm would of necessity vary the share of the rewards that should go to either party. Consequently, such variations have a vital bearing on the problems of the determination of an equitable rent.

The total capital used on the average farm has varied considerably since 1860, but practically all of the increase in total farm value occurred during the past 20 years (see Table 8). The smallest average total value was reached in 1880, at the end of the decline

¹¹ See Complete Statutes of Texas, pp. 13-14 and 745. Aliens of countries which have treaties with the United States providing for the right of ownership in this country and aliens of countries which allow ownership rights to citizens of the United States are excepted from the provisions of this law.

¹² The extent to which the bonus system was practiced is not known, because the bonus provision of the rent contract was usually kept a secret and was very unpopular with renters in general (see Univ. of Tex. Bul. No. 21, 1915, Chapter VI). However, by 1910 state-wide attention was given to the subject, which culminated in the organization of the Renters' Union of America in 1911. The subject of rent and land problems in general became the main issue for the gubernatorial campaign of 1914, and the successful candidate was elected mainly because of his advocacy of an antibonus law.

¹³ See Chapters IX, X, and XI of Taylor's "Agricultural Economics."

in total farm value which was caused mainly by a reduction in the size of the farm.

TABLE 8.—*Total value of the average black land farm and distribution of this value, by decades, since 1860.*¹

Census year.	Average acres per farm.	Average total farm value.	Per cent of farm value in land and buildings.	Per cent of farm value in equipment.	Per cent of farm value in machinery.	Per cent of farm value in live stock.
1860.....	533.3	\$4,860	61.5	38.5	3.5	35.0
1870.....	225.7	1,923	63.9	36.1	2.6	33.5
1880.....	133.1	1,532	78.8	21.2	4.2	17.0
1890.....	114.3	2,493	81.4	18.6	2.8	15.8
1900.....	91.8	2,730	82.8	17.2	3.7	13.5
1910.....	96.0	5,306	86.6	13.4	2.7	10.7
1920.....	90.6	11,694	90.3	9.7	3.2	6.5

¹ Computed from United States Census data.

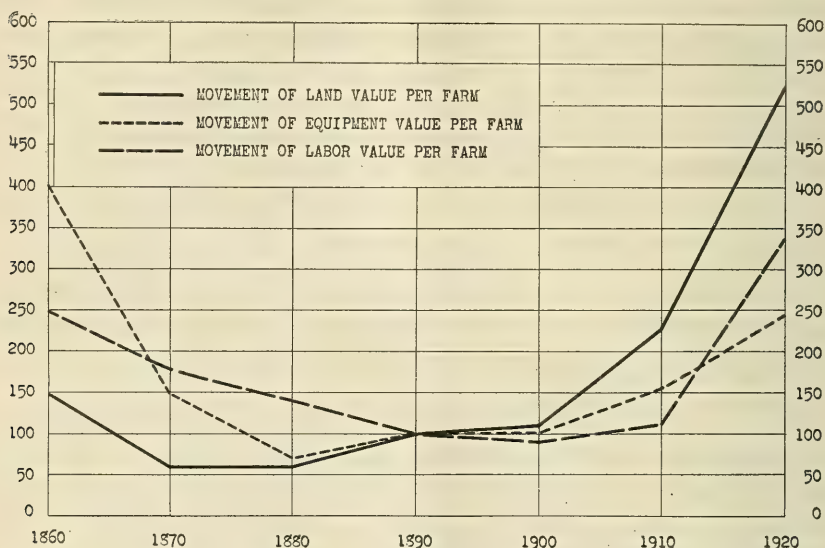


FIG. 3.—Movement of the value of land, equipment, and labor used on the average black land farm, by decades since 1860.

Prior to 1890 the size of the farm and the system of farming changed so radically that the actual and relative amounts of capital in land and buildings and in equipment were greatly affected. However, since 1890 farm values have been affected very little by changes in size of farm and in the system of farming, and land values have gradually and consistently increased in proportion to equipment values. This increase possibly indicates to a certain extent the relative future trend of the values of equipment and land if the present system of farming is maintained.

If equipment value were the only value contributed to the farm business by the tenant, an equitable adjustment of rents would have

necessitated a gradual increase in rents each decade since 1880—provided none of the increase in land values was speculative in nature. But the value of the labor, management, and risk contributed by the tenant to the farm business are relatively much greater than the value of his contribution in equipment. Consequently, equipment and land values alone do not constitute a basis for an equitable adjustment of rent.

Striking variations in the relative values of the factors of production on the average black-land farm have occurred since 1860. These variations are shown in Figure 3. Changes in the size and system of agriculture before 1890, as stated above, influenced the variations in both the actual and relative values of the factors of production, and for this reason 1890 was taken as the base for the index figures from which the graph was made.¹⁴ During these changes rent has not changed, except as price levels alter the value of rent in dollars, for the one-third and one-fourth share rent has been the customary rent since the early days of renting.¹⁵

Equitable rent adjustment must be based on a fairly accurate valuation of the contributions furnished respectively by landlord and tenant, and since these values vary greatly, it is not reasonable to suppose that a set share rent, such as is legalized in the antibonus law, can possibly adjust itself to these variations in the value of the factors of production. This adjustment can only be accomplished by a careful and scientific appraisal of the value of these factors as a basis for apportionment of the rewards of the farm business.¹⁶

ECONOMIC ASPECTS OF THE FORMS OF TENURE.

FARM ORGANIZATION.

For the discussion which follows, of the forms of tenure, operators are classified as (1) *share croppers*, (2) *share tenants*, (3) *owners*

¹⁴ The index numbers on which graphs are based are calculated as follows: The index numbers of land and equipment values per farm were calculated from data given by decades in Table 8, p. 14. The index figures on the amount of labor used on the average farm were calculated by finding the total country population in the 19 black-land counties by subtracting from the total population the population living within incorporated cities and towns. The ratio of the number of people engaged in agricultural pursuits to the country population in the State as a whole was then applied to the total country population of the black land, which gave the estimated number engaged in agricultural pursuits in the black land. This figure for each decade divided by the number of farms for the decade gave the following average number of people engaged in agricultural pursuits per farm: 1860, 4.16; 1870, 3.67; 1880, 3.32; 1890, 2.25; 1900, 2.18; 1910, 2.11; 1920, 2.04. The average number of persons per farm engaged in agricultural pursuits was weighted by the average wage paid farm labor, other than harvest labor (see U. S. Bureau of Statistics Bulletin 79), which gave the final figures on which the index figures for labor were based.

¹⁵ See "Texas the Home of the Immigrant from Everywhere," Texas Bureau of Immigration Bulletin of 1873.

¹⁶ Prof. William E. Leonard, formerly of the University of Texas, has suggested a county rent board with official standing and with power to adjust rents. This seems to be an excellent plan for a more scientific adjustment of rents. See Univ. of Texas Bulletin No. 21, 1915, p. 123.

additional, or (4) *owner operators*.¹⁷ The term *owner* is used to include both owners additional and owner operators; and the term *tenant* is used to include both share croppers and share tenants.

Of the 368 farmers from whom data were taken, 192, or 52.2 per cent, were share tenants; 83, or 22.6 per cent, were owner operators; 65, or 17.7 per cent, were share croppers; 26, or 7 per cent, were owners additional; and 2, or 0.5 per cent, were cash tenants.¹⁸

SIZE AND VALUE OF FARMS OF DIFFERENT TENURE CLASSES.

The average size of the farms varied considerably with each form of tenure, as will be noted from Table 9. Share croppers, who had the smallest farms, had exactly half as many acres on the average as owner operators, who operated 118.2 acres each. Share tenants had only 14 acres less on the average than owner operators, while owners additional, who had the largest farms, operated 159.2 acres each.

TABLE 9.—Average size and value of farms and the distribution of farm values for the different tenure classes.

Present tenure class.	Number of operators.	Average acres per farm.	Average value per farm.				Average value per acre of—	
			Total farm value.	Value of land and buildings.	Value of equipment.	Value of buildings.	Farm land without buildings.	Equipment.
Share croppers	65	59.1	\$10,945	\$9,841	\$1,104	\$703	\$155	\$19.00
Share tenants	194	104.2	19,162	16,489	2,675	1,144	148	26.00
Owners additional.....	26	159.2	26,747	22,995	3,752	2,061	132	24.00
Owner operators	83	118.2	23,408	19,078	3,330	2,215	143	28.00
All operators.....	368	103.3	18,981	16,359	2,622	1,374	145	25.40

¹ Includes two cash tenants.

As a class, owner operators are better able than any other tenure class to increase the size of their operated farms, for their average net worth is more than twice that of owners additional and more than eight times the average wealth of share tenants. The fact is

¹⁷ *Owner operators* own all the land they operate. *Owners additional* own part and rent part of the land they operate. *Share tenants* rent all the land they operate and furnish all labor and equipment used on their farms, and as a rule receive two-thirds of the grain and three-fourths of the cotton raised. *Share croppers* rent all their land and furnish only the labor used in operating their farms, the equipment, feed, repairs, etc., being furnished by the landlord and the crops being shared equally. There are two distinct classes of croppers in the black land, these classes being known locally as *half renters* and as *half hands*. The half renter usually gets all the land he can operate and does little work for his landlord. The half hand is allowed only enough land to "hold" him during the year, the aim of the landlord being to use the half hand most of the time working on his (the landlord's) farm. The cropper farm, therefore, is frequently a part of a larger unit of farm organization and is discussed throughout this bulletin from the tenure and operator viewpoint rather than from the organization viewpoint.

¹⁸ These two cash tenants were included with the data on share tenants throughout the bulletin.

that owing to advanced age, many owner operators are gradually decreasing the size of their farms as they approach retirement time. This class of farmers has been called "retreating farmers."¹⁹

The average size of share croppers' farms is small as a result of the fact that probably half of them had less land than they needed in order to utilize their entire time.²⁰ Owners additional as a class are successful farmers who are striving to expand their farm business, and do so by renting additional land.

The average total value of the farm and its equipment for all tenure classes was \$18,981; and the relative values of farms for different forms of tenure have the same order as the order of the sizes of farms for the different tenure classes (see Table 9). However, it will be noted that owner-operator farms have relatively a much higher value in proportion to size than do the farms of owners additional.

That the average value of farms of owner operators is relatively large is due in part to the fact that they have more than twice the wealth of owners additional (see Table 22) and can have and do have better houses and farm equipment. Furthermore, many of the owner operators are decreasing the size of their farms as they approach retirement age without reducing proportionately their building and equipment value.

An interesting fact brought out in connection with equipment value per acre is that share tenants are almost as well supplied with equipment as are owner operators. One of the serious drawbacks of the one-crop system practiced in the region is that the tenant can not profitably invest all his surplus savings in his farm business, and the resultant tendency for some tenants to overinvest in equipment probably explains the relatively high average equipment value for them as a class.

The data on value of buildings show strikingly one of the evils of tenancy in this area. The average value of buildings on share-tenant farms is about one-half, and on share-cropper farms less than one-third of the average value of buildings on the farms of owner operators. Most of this difference is accounted for in the difference in value of dwellings (see Table 29).

However, there is a lack of buildings for housing machinery on the farms of all tenure classes. Investigation on this question revealed the facts that (of those reporting) 120 tenants had no buildings for the protection of machinery from the weather, 10 had part of their machinery under shed, and 16 had all machinery under shed. Forty-five owners had no machinery under shed, 9 had part of it

¹⁹ See Wisconsin Agricultural Experiment Station Research Bulletin No. 44, p. 6.

²⁰ Eighteen of the 65 croppers had 30 acres or less.

under shed, while 21 had all of their machinery protected from the weather.

Of the various tenure classes, share croppers farm the most valuable land (after deducting building values). Furthermore, the land farmed by share tenants is higher in price than the land farmed by either of the owner classes. This situation, common throughout the cotton belt, is not the result of competition between operators, the most efficient getting the best land, but it is rather the result of competition between systems of farming, with the operators who will grow the most cotton getting the best land. This is largely due to the fact that the owner believes cotton yields him the highest net returns, and to the fact that when cotton is raised the owner can easily ascertain what his share of the crop is and can easily market it.

OTHER FARMS OWNED BY OPERATORS.

Owners who have farms they do not operate usually have acquired the additional farms as investments, or in order to have land for children who are growing up (Table 10). A larger proportion of owner operators than of any tenure class own farms they do not operate; over one-third of all in this class own additional farms, as compared with about one-fifth of owners additional and one-eighth of share tenants. Furthermore, the average owner operator's equity in farms owned but not operated is nearly twice as large as the average equity of owners' additional, and more than four times as much as the average equity of tenants in the farms they own but do not operate.

Black-land tenants usually say that the land in the region is priced higher than its productive capacity warrants, and that if they buy they will buy where land is cheaper. Evidently, this belief has influenced the purchase of farms owned by share tenants, for the average value per acre of the land owned by share tenants was \$74, while the average value of the land they operated was \$175 per acre.

TABLE 10.—*Operators who own farms they do not operate, and the size, value, and equity in these farms, for the different classes of tenure.*

Present tenure status.	Number of operators who owned other farms.	Per cent of all operators in tenure class.	Number of other farms.	Average acres per operator.	Average value per operator.	Average equity per operator.	Per cent of value in equity.	Average age of operator.
Share croppers.....	2	3.1	2	29.0	\$1,350	\$1,200	88.8	48
Share tenants.....	25	12.8	27	115.2	8,559	5,882	68.7	43
Owners, additional...	5	19.2	8	207.6	20,726	13,274	64.4	44
Owner operators.....	29	34.9	53	209.5	26,589	25,515	95.9	49

THE CROPS GROWN.

The average black-land farmer, regardless of his tenure, is a one-crop farmer; for owners had about six-tenths, share tenants over two-thirds, and share croppers almost four-fifths of all their crop land in cotton. Moreover, approximately two-thirds of the total area of the 368 farms was in cotton in 1919 (Table 11).

TABLE 11.—*Proportion of all farm land in crops, proportion of all crop land in various crops, and operators classified by the per cent of all crop land planted to cotton, by tenure classes for 368 operators.*

Present tenure status.	Per cent of all farm land in crops.	Per cent of all crop land in—				Per cent of all operators in each tenure group whose per cent of cotton acreage to all crop acreage is—			
		Cotton.	Corn.	Small grain.	Other crops.	90 per cent and above.	75 to 90 per cent.	50 to 75 per cent.	Below 50 per cent.
Share croppers.....	92.2	78.7	13.4	5.5	2.4	52.3	24.6	20.0	3.1
Share tenants.....	91.3	67.1	12.9	15.9	4.1	1.6	29.0	59.6	9.8
Owners additional.....	85.7	56.1	12.1	27.4	4.4	-----	11.6	57.8	30.8
Owner operators.....	85.9	62.5	16.0	16.2	5.3	-----	13.4	64.6	22.0
All operators.....	87.6	66.0	13.6	16.1	4.3	10.1	23.5	53.6	12.8

The extent of the dependence that the black-land farmer places in cotton is not adequately shown by these data. Corn is grown primarily to feed live stock used in producing cotton, and in this sense it practically becomes a cost in the production of cotton. Because this policy so largely governs the growing of corn, the percentage of corn to all crops varies but little with the different tenure classes.

Over half of all croppers have 90 per cent or more of their crop area in cotton. And, while practically none of the operators in the other tenure classes go to this extreme, only 15 per cent of them have less than 50 per cent of their crops in cotton.

In this connection it is well to note that the conservation of soil fertility is rarely considered by operators in any of the tenure classes. However, it will be seen that owners probably do more to conserve soil fertility than do tenants, for owners alternate grain crops with cotton to a greater extent than do tenants.

RENT CONTRACTS AND RELATION BETWEEN LANDLORD AND TENANT.

Customary renting practice forms the basis for practically all renting contracts. In fact, nearly all rent contracts are nothing more than an agreement between the landlord and tenant that "customary renting practices" shall be followed. Such a contract, no doubt, seems indefinite and broad in its interpretation, but customary

practices are quite well known and there is less friction due to misunderstanding between landlords and tenants than one would expect.

The principal objection to this method of renting is that it does not induce changes in the rent contract as the tenant develops and as he and his landlord learn to appreciate each other better through experience.²¹ Written contracts would probably induce a greater care in working out the details to fit changed conditions.

Data on the details of the rent contracts of 259 tenants are given in Table 12. Of those reporting on the question, only 13.5 per cent had written contracts. Only 1 share cropper out of 61 reporting had a written contract. Only 4 contracts out of a total of 239 ran for more than a year.

TABLE 12.—*Provision of rent contracts on 259 rented farms.*¹

Tenure class.	Nature of contract.				Duration of contract.				Subrenting privileges.		
	Verbal.		Written.		One year.		More than one year.		Number who were allowed to subrent.	Number who were not allowed to subrent.	Number not reporting.
	Number.	Per cent of those reporting.	Number.	Per cent of those reporting.	Number.	Per cent of those reporting.	Number.	Per cent of those reporting.			
Share croppers.....	60	96.8	1	1.6	59	98.3	1	1.7	10	19	36
Share tenants.....	155	82.4	25	13.3	168	98.8	2	1.2	67	41	85
Owners additional.....	2	20.0	8	80.0	8	88.9	1	11.1	5	2	13

¹ Frequently no dependable information on certain points could be obtained, hence the number of operators on which the data in this table are based varies considerably.

The privilege of subrenting is not usually allowed, and frequently is not mentioned in contracts, since a provision in the landlord's lien law makes it illegal to subrent land without the landlord's consent. It will be seen, however, that a greater proportion of share tenants than of share croppers are allowed to subrent.

Thirty-six farms were found where the landlord had agreed to pay the tenant for improvements put on the place, provided the landlord gave his permission to have the improvements put on the farm. Usually it was agreed that when the tenant left the farm the landlord would buy the improvements himself or require the tenant following to buy them. This provision would unquestionably be desirable for most rent contracts. Landlords frequently complain that they can not repair old improvements or put new ones on the

²¹ Many cases were found where absolutely nothing as to details of rent contracts was said for years, the tenant simply asking his landlord, some time in the fall, if it were agreeable to remain on the farm another year.

farm, because their returns from the farm do not justify such expenditures, or because tenants will not take care of these improvements.

If legal provision were made for the compensation of tenants for improvements put on with the landlord's consent, the present problem of tenant housing would be less acute, landlords would not so often be accused of lack of interest in this problem, and the mutual interest in the farm arising from a joint ownership of improvements would make for a more stable and reliable tenantry. Moreover, with such a provision, tenants would be able to invest their savings in the farm business, which is possible only to a limited extent with the prevailing crop and renting system. This lack of opportunity to accumulate by gradually increasing their investment in the farm constitutes one of the most serious drawbacks to the tenure and financial progress of the tenant in this area.

The amount of supervision given the tenant by the landlord is largely dependent on the location of the landlord's residence with reference to the rented land. Data on the residence of the landlords, given in Table 13, show that very few of the landlords of share croppers live outside of the county, and that 42.2 per cent live near the farm of the cropper. On the other hand, only one out of eight landlords of share tenants live near the tenant's farm, and over one-fifth of them live in another county.

TABLE 13.—*Residence of landlords of share croppers and share tenants.*

Class of tenants.	Landlords who live near tenant farm.		Landlords who live in same county.		Landlords who do not live in same county.	
	Number.	Per cent of all reporting.	Number.	Per cent of all reporting.	Number.	Per cent of all reporting.
Share croppers	27	42.2	31	48.4	6	9.4
Share tenants	23	12.2	127	67.6	38	20.2

The recapitulations for the tax rolls of Bell, Hill, and McLennan Counties for 1919 show that only 8.4 per cent of all the land outside of incorporated cities and towns was owned by nonresidents of the county in which the land was located. Only 17 of the nonresidential landowners in Bell County in 1919 lived outside of Texas, and none lived outside of the United States.

It will be noted from Table 14 that about half of all share croppers were subject to supervision by landlords. The extent of this supervision is in a way indicated by the average number of visits the landlord makes to the farm during the year, namely, 85 for each of the

17 share croppers who reported on this question.²² Share tenants receive very little close supervision. Nine out of each ten said they were given no supervision by their landlords, and the average number of visits by landlords was only 5 during the year.

TABLE 14.—*Supervision of tenants by landlords.*

Tenure class.	Operators whose landlords give no supervision.		Operators whose landlords give "little" supervision.		Operators whose landlords give close supervision. ¹		Visits of landlord per year.	
	Number.	Per cent of those reporting.	Number.	Per cent of those reporting.	Number.	Per cent of those reporting.	Number operators reporting.	Average number of visits per operator.
Croppers.....	30	51.7	5	8.6	23	39.7	17	85
Tenants.....	161	91.6	8	4.5	7	3.9	100	5
Owners additional...	9	100.0					3	1.7

¹ "Close supervision" as here used means close attention and direction as to how and when the details of farm work should be done; also "no supervision" does not imply that the landlord does not keep in touch with the farm work, but, rather, that he leaves the tenant to work out the execution of the details of farm operations.

This great difference between the amounts of supervision given by landlords of the two renting classes accounts in part for the social stigma popularly placed on the cropper stage. It is unfortunate that conditions foster this dislike for the cropper stage, for cropper farming can be made to exercise a useful and desirable function in the tenure system of the black land. It offers the young, inexperienced man, who has little capital, an opportunity to assume part of the risks involved in operating a farm, with a good chance of receiving in return an increased reward over farm wages as payment for assuming part of the responsibilities and risks of an operator. If landlords were more careful about the nature of their supervision and granted more privileges as regards raising a garden, and keeping poultry, and a cow, they would do much to obviate the popular dislike for the cropper stage.

Operators were asked if they noted any changes taking place in renting practices. Of 168 operators answering the question, 126 noticed no changes, which probably means a lack of observation on the part of most of the operators. Many, however, believe that the bonus system was on the decline and that it was getting easier to obtain desirable share-tenant contracts from the viewpoint of the tenants.

²² It should be borne in mind that the average man does not like to answer questions of this nature, and for this reason answers were not secured from all operators. Furthermore, some of the answers secured were possibly misleading, and where there was doubt concerning the answer given and no verification could be had it was discarded.

INCOMES FOR THE DIFFERENT TENURE CLASSES.

COMPARATIVE ECONOMIC CONDITION OF AREA IN 1919.

Before discussing the incomes earned in 1919 on the farms surveyed it is well to consider comparative data on the general economic conditions prevailing in the black land during that year. The year was characterized by unusually high prices of products, especially cotton, by a yield of cotton that was much below the average for the black land, and by unusually high costs of production. Furthermore, the fall of the year was unusually wet and the picking of cotton was thus delayed to a considerable extent, resulting in an inferior grade of cotton in most cases.

The total production of cotton for the 19 black-land counties in 1919 was 89.1 per cent of the average production for the 20 years, 1900 to 1919, inclusive.²³

The production of cotton for the 6 counties in which most of the survey data were taken was 74.4 per cent of the 20-year average production for these counties. Without doubt the acreage of cotton had not been reduced after 1916 (Census data show an increase of 11.8 per cent from 1910 to 1920), for the high prices prevailing from then until 1920 did much to stimulate the farmer to plant more cotton, although the low yields during these years tended to prevent the realization of profits that otherwise might have resulted from high prices. The average of monthly prices of cotton received by producers for 1919 was 29.6 cents per pound, the highest price received during the 9 years from 1911 to 1919, inclusive.²⁴

The economic situation of the black-land farmer in 1919 is further shown in Figure 4. While the trend of prices of articles which the farmer bought and the trend of farm wages were steadily and sharply upward after 1916, the upward trend of gross receipts from cotton (represented by the total value of cotton produced in Ellis and Williamson Counties) was relatively much less abrupt.

It is doubtful, therefore, if the average income of farmers for whom survey data were taken was larger than usual in 1919, since the cotton crop on which they so largely depend was less than three-fourths of an average crop, and at the same time all costs were unusually high and weather conditions unfavorable.

²³ Figures on total cotton produced are computed from Census publications which report the total number of bales ginned annually for each county. The figures on production are on the basis of 500-pound bale equivalents.

²⁴ The average prices received by producers for their cotton during these years were as follows: 1911, 12.7 cents; 1912, 10.6 cents; 1913, 12 cents; 1914, 10.6 cents; 1915, 8.9 cents; 1916, 13.5 cents; 1917, 21.5 cents; 1918, 29.5 cents; 1919, 29.6 cents. (From December, 1920, Crop Reporter, U. S. Bureau of Crop Estimates, p. 144.)

FARM INCOMES AND NET RETURNS ON CAPITAL.

The *farm income* is the difference between receipts and expenses.²⁵ If from this farm income we deduct the value of the operator's labor and add to the remainder the value of the family living furnished by the farm, we get a figure that represents the net return to the farm and its equipment for their services in production, regardless of what portion of this return goes to the landlord or to the tenant. In other words, this figure represents the net increase of wealth attributable to the farm, irrespective of tenure.²⁶ The income for share tenants' farms, when figured in this way, compares favorably

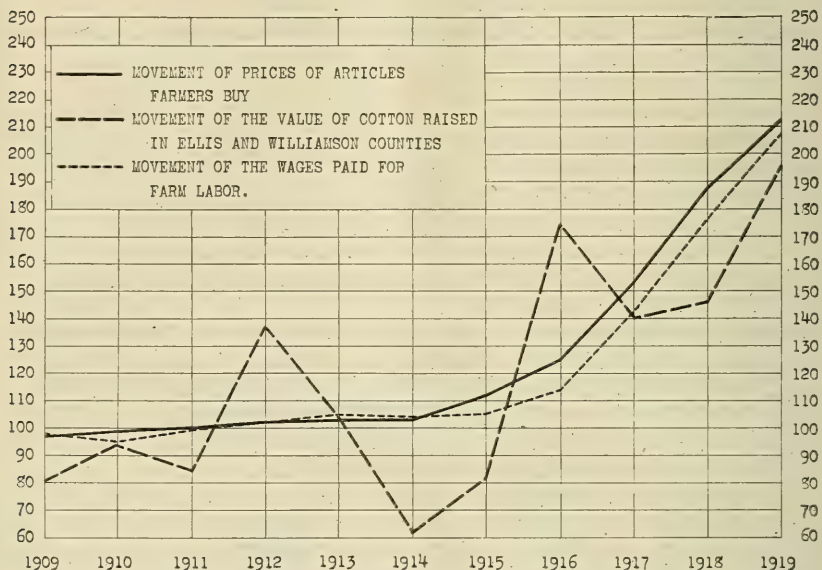


FIG. 4.—Movement of the prices of articles farmers buy, of farm wages, and of the value of cotton raised in Ellis and Williamson Counties, Tex. (5-year average 1909–13 equals 100).

with the income of the farms of the two owner classes, while the income from cropper farms is only about two-thirds as large as the income from farms of the other tenure classes.

²⁵ Incomes were not calculated by the usual receipts and expense method, but by taking inventories of the farm business at the beginning and the end of the year. To the difference between inventories was added any sum taken out of the farm business and put in outside enterprises, and the sum of all family living expenses. From this sum was taken receipts from sources outside of the farm business. This gave a basic figure from which the various income figures were calculated.

²⁶ It will be seen by comparing items 1 and 2 of Table 15 that the value of the operator's labor is not as great as the value of family living furnished by the farm, hence item 2, which includes the family living furnished by the farm but does not include the value of the operator's labor on the farm, represents the net return of the farm more nearly than item 1. Items 1 and 2, however, include the value of the operator's management and the value of uninsured risk; that is, nothing is deducted for these. The value of family labor on farm is considered a farm expense.

TABLE 15.—*Analysis of incomes of 343 black-land farms and farm operators, by tenure classes.*

Item of income.	For 62 share croppers.	For 179 share tenants.	For 26 owners addi- tional.	For 76 owner- operators.	For 343 operators of all tenure classes.
1. Farm income ¹	\$1,217	\$1,678	\$1,609	\$1,757	\$1,607
2. Farm income plus value of family living furnished by farm and minus value of operator's labor ¹	1,255	1,812	1,866	1,911	1,734
3. Ratio of net return to the total farm capital ²	13.4	11.4	8.2	10.3	11.3
4. Operator's labor income (interest charged on all farm capital at 7½ per cent).....	528	702	-61	317	498
5. Operator's labor income, plus family living from farm (interest at 7½ per cent deducted).....	775	1,120	480	656	906
6. Operator's labor income plus family living from farm (interest on capital in equipment at 7½ per cent and on capital in land at 4½ per cent deducted)....	³ 775	³ 1,128	731	1,293	1,081
7. Operator's rate of net return on his share of farm capital.....	(4)	45.7	11.2	10.7	33.7
8. Landlord's rate of net return on his share of farm capital.....	6.6	5.6	7.2	.....	5.9
9. Actual disposable net income from labor of oper- ator and family and from farm investment (interest and rent when paid out not included ⁵).....	1,094	1,513	1,646	2,429	1,649
10. The family's net accumulation of wealth for the year.....	149	291	213	613	327

¹ No interest on farm capital, whether borrowed or not, is deducted in these figures, and the data are based on the operated farm as a whole, regardless of the tenure of the operator. Each tenant or cropper farm is here considered a farm as defined by the Census. The value of family labor on farm is considered a farm expense.

² Calculated on the basis of item 2.

³ Since rent instead of interest is deducted in calculating the income of tenants, these figures are the same as item 5 above, except for share tenants, 36 of whom had \$31,824 invested in improvements on the farms they operated which caused their labor income to be increased \$8 on an average in item 6.

⁴ Croppers own no farm capital, hence no calculation was made for them.

⁵ In this figure no allowance is made for rent and interest on farm capital unless these are actually paid out. Therefore, the figure for an owner-operator whose farm is not mortgaged has no rent or interest on farm capital deducted, but for operators who actually paid either rent or interest, or both, these items were not included in the figure.

On the other hand, the ratio of net return to the capital invested in the cropper farm (item 3) was more than the ratio of net return to capital for any of the other tenure classes, and in this regard share tenant farms also exceeded the farms of owners. It would seem, therefore, that net social wealth is increased proportionally most when land is operated in the black land by tenants.²⁷ However, it should be remembered that material wealth is sometimes created at a loss to the intellectual, social, and political life of people; and, judging from the effects of tenancy on the education of tenants' children (see pp. 56-60), such losses would far outweigh any possible increase in social wealth that might result from an extension of tenancy in the black land.

The rate of net return on the capital invested in the farm can not well be used as an indication of the relative efficiency of the operators

²⁷ Tenant farms, as has been shown, have a higher percentage of their acreage in crops, a smaller proportion of farm capital in buildings, and no doubt less land is used in yards, dwelling sites, and other nonproductive purposes than is the case with farms operated by owners, tending to give a higher ratio of net return on the capital invested in the tenant farm. With this exception, however, it is doubtful if the less diversified farming of the tenant yields a greater net social gain on the capital invested over a long period of time than the more diversified farming of owners.

of the different tenure classes in this area. Considerations that are not of an economic nature influence operators differently. For example, some of the most efficient operators may not wish to grow large acreages in cotton, thus running the risk of being compelled to keep their children out of school to get it picked; and prefer to grow small grain on much of their land, even though their net return on capital is thereby made smaller.

The *operator's labor income*, as used in most farm-management surveys, is the net surplus left to the operator, for his labor and management, after deducting all farm expenses (including interest on the farm capital) from receipts, not including the family living furnished by the farm as a receipt. The labor income given under item 4, Table 15, conforms to the above definition, deducting interest at $7\frac{1}{2}$ per cent—the average interest paid for first mortgage loans on the farms surveyed.²⁸ In all cases where land was rented, the actual rent paid was deducted and not an assumed rate of interest on the estimated value of the land.

Item 5 is similar to item 4, except that the value of the family living is included as a receipt. And item 6 is the same as 5, except that on farms operated by owners the interest on land value deducted was $4\frac{1}{2}$ per cent, which was the average return on the capital invested in cash-rented farms, in 7 black-land counties in 1919.²⁹

Item 6 represents more correctly the net value that the farmer receives for his farm labor and management than do either of the other two items on labor income.³⁰ It will be noted that when a flat rate of $7\frac{1}{2}$ per cent is deducted to arrive at labor income, both tenant classes make a better showing than either of the owner classes. The 26 owners additional have the lowest average labor income—averaging a loss of \$61 each for their labor and management. Yet in this calculation the interest deducted on the value of the land was not in excess

²⁸ This is the average weighted interest rate on first mortgages, weighted by the total amount of loans under the different interest rates.

²⁹ This rate of return on cash-rented farms is based on compilations made from schedules of the 1919 census on 331 cash-rented farms in Collin, Falls, Lamar, Limestone, Milam, Navarro, and Travis Counties. This ratio does not represent the net return to the landlord, as taxes, upkeep, and other expenses are not deducted.

³⁰ The present price of land is the sum of a number of different values. It represents use values in production, the value of anticipated increases in future income-yielding power, and the value of the social, community, and home uses which go with the ownership of the farm. The man who buys a farm gets all values attaching to the ownership of the land, but the renter gets only its present use values (including in some cases part or all of the home, social, and community values), and should pay for these only. For this reason the cost of land, in calculating labor income, should be the cost of its present uses. Since a current rate of interest on the capital invested in land and buildings covers all values that go to make up the price of land, it may be too much to charge for the use of the land for the year's operation. Share rent, besides paying for the use of the land for the year, covers part of the risk in the business that the landlord assumes, but the landlord assumes comparatively little risk when he rents for cash. On account of these conditions it is believed that cash rent offers the *best available figure* as a basis for calculating the cost of land as a factor of production.

of the interest paid in the region for loans under reasonably favorable conditions.

In practice the operator does not calculate his labor income in this manner. He knows that what he receives from the farm for family living materially reduces his family expenses, correspondingly increasing his reward for labor and management. Furthermore, if he is an owner, knowing that land values have steadily risen in the past, he assumes that this rise in the future will supplement the low return that his land yields from its present use. Moreover, he frequently is influenced to pay more for his farm than he otherwise would pay, because he desires to own his home. Consequently, part of the land cost is considered part of his family expenses. In short, he does not charge all of the present cost of land to its present operating use. Hence, the landowner realizes that he has not in any sense lowered his power to earn wealth by becoming an owner; he knows that he has bought new personal satisfactions and future incomes which he thinks are worth the price paid for them.

Thus, when these values are not deducted from the net surplus which is the reward of the operator for his work and management (see item 6) the result is quite different from that shown in item 4. The average labor income of owner operators increased from \$317 to \$1,293, and the increase for the labor income of owners' additional income is from minus \$61 to plus \$731.

The average rate of net return on the investment of the share tenant in the farm business is more than four times as large as the rate of return to owners on their investment (see item 7). This situation is quite generally realized, and is a strong stimulus to the development of tenancy in the area.

The pecuniary considerations responsible for this tendency may be further shown by presenting the things that would confront a share tenant who contemplated buying the average farm operated by the share tenants interviewed. The average value of the farms operated by share tenants was \$16,489 (see Table 9), and the average net rent paid to the landlord in 1919 was \$924.²¹ Assuming that the tenant could pay one-third of the price of the farm in cash,²² the interest at $7\frac{1}{2}$ per cent on the remainder would amount to \$825 for the year, leaving a remainder over rent of \$99 to apply as payment for the interest on the cash payment and upkeep. Interest on the cash payment would amount to \$412, and after taking the remainder of \$99 from this, the tenant would be short \$313 as an owner of the place he rented in 1919. For this \$313 he would have to get

²¹ Net rent as used here is the gross rent from the land less taxes and upkeep.

²² The approximate per cent paid in cash by owners who have bought since 1900. (See Table 20.)

his reward from the privileges of owning the farm, including the right to all increases in land value and to any intangible values the tenant may place on ownership.

Share tenancy, therefore, yields the tenant a greater immediate cash return than he could earn with an equivalent expenditure of cash and labor as an owner operator, and this condition tends to increase the period of tenancy of operators, and thus the per cent of tenancy. A rigid enforcement of the antibonus law, if the legally specified share is less than the net return attributable to land after all expenses are deducted (not including rent to be paid as an expense), would tend to make land values lower than they would be were there no such law, and the enforcement of the law under the conditions outlined would, without doubt, tend to lessen the stimulus to tenancy mentioned above.

Land owners in the black land have frequently said their rents were too small to yield them a return on the capital invested in the land equivalent to the return yielded on the same capital if it were put in equally safe alternate investments. In 1919, a year favorable to landlords, the landlord's net return on his farm capital was less for both tenant classes than the average first mortgage loan rate. The average rate of net return to the landlords on share-tenant farms was 5.6 per cent and on cropper farms 6.6 per cent (see item 8, Table 15).

However, if the returns of the landlord from rent in the past were supplemented by his net returns from increases in land values it would be found that his total net gain as a land owner has been very attractive. By reference to data in Table 7, it will be noted that land values in the black land as a whole, including improvements placed on the land, have increased each decade since 1870, and by increases varying from 39 to 144 per cent.

In order to give the proper emphasis to this important phase of the tenure problem, data on each land purchase were taken from all operators interviewed who had bought land in the black land. These data are summarized in Table 16. In each individual case the increase or decrease in land values was calculated by deducting the value of improvements (buildings, fences, drainage, clearing, etc.) from the gross increase or decrease. All increases are calculated in terms of their equivalent in interest compounded annually on the original investment, which is, in reality, counting the original investment and the accumulated increase as reinvested capital for each year.

It will be noted that only 3.7 per cent of all purchases were made at a loss, and that these places were usually kept for a very short time. Practically no losses were recorded on purchases where the

land was kept an average of over three years. Therefore, land investment has been exceptionally safe to these people.

TABLE 16.—Changes in the value of land bought in the black land by the operators interviewed, expressed in equivalents of interest compounded annually on the original investment.

Changes in land values equivalent to an annual compound interest of—	Land bought and sold.						Land bought and still owned.					
	At a gain.			At a loss.			At a gain.			At a loss.		
	Number of cases.	Aggregate years held.	Average compound interest.	Number of cases.	Aggregate years held.	Average compound interest.	Number of cases.	Aggregate years held.	Average compound interest.	Number of cases.	Aggregate years held.	Average compound interest.
0 per cent.	11	28					4	6				
Above 0 and to 4 per cent. .	5	25	3.5	1	5	2.0	23	266	2.6	3	32	0.7
Above 4 and to 8 per cent. .	19	118	6.4	3	7	6.0	72	1,148	6.5			
Above 8 and to 12 per cent. .	19	132	10.5				48	643	9.9			
Above 12 and to 16 per cent. .	8	32	14.9	1	1	15.0	11	77	14.2			
Above 16 and to 20 per cent. .	6	19	17.8	1	3	17.0	4	28	17.0			
Above 20 and to 25 per cent. .	7	21	23.3	1	1	22.0	8	54	22.5			
Above 25 per cent.	7	12	39.6				5	11	35.6			
Total number of cases	82			7			175			3		

The average weighted per cent of annual net increase in land values³³ calculated annually, for *land bought and then sold*, was 9 per cent, and for the land that was bought and held, 7.9 per cent. In other words, the increase in land values was the equivalent of an annually compounded interest on the original investments of 9 and 7.9 per cent. The net return from these 267 purchases of land from increases in its value alone, therefore, has been enough to make the land an attractive and safe investment, to say nothing of the return in rents.

General realization of these facts has, without doubt, been a most potent influence in the rapid increase in land value during the last 20 years. Whether or not it has resulted in speculative inflation of land values is impossible to say from available data. However, unless present price levels in general are maintained, there is the possibility of much loss and social unrest in the present situation.

The farmer's net surplus wealth accumulated during the year depends on the amounts of his capital that he owns, the labor that he himself can furnish, and the amounts of these he must hire. The actual *disposable incomes* of operators, in which interest and wages are deducted only when actually paid, are shown in item 9, Table 15. These figures include all value received by the farmer from the labor of himself or family on and off the farm, and values of family living furnished by the farm.

³³ The rates of increase were weighted by the aggregate years the land was owned as given for each group in Table 16.

The disposable income varies from \$1,094 for croppers to \$2,429 for owner operators—a difference of \$1,335. This difference exceeds the difference in the labor incomes of the two classes by \$817 (compare with item 6), which is largely the results of the earning power of the greater amount of wealth of the latter class. The cropper pays for all his capital and has a little less than half as much in use as has the owner operator (see Table 9). Owners additional had only a slightly larger disposable income than share tenants, although the former had 4.1 times as much net wealth as share tenants had, which is largely explained by the conditions already discussed that make the share-tenancy stage relatively more profitable to the average tenant than are the owner stages (see p. 27).

Out of this disposable income the operator had to pay all family expenses, and the remainder (item 10) represents the net accumulation of wealth for the year from the farming efforts of the operator and his family.³⁴ The cropper saved 13.6 per cent of his disposable income; the share tenant, 19.2 per cent; the owner additional, 12.9 per cent; and the owner-operator, 25.2 per cent. It will be noted that the larger the disposable income the greater the amount that was spent for family living, but that the per cent spent for family living decreases with the increase of disposable incomes, except with owners additional.

The actual net accumulation of wealth of the average family in 1919 was \$149 for croppers, \$291 for tenants, \$213 for owners additional, and \$613 for owner-operators. For all except the latter class these figures may seem somewhat small. In fact, it is probable that they are smaller than usual for reasons stated at the beginning of the discussions of incomes.

If the average share tenant should buy the farm he operated in 1919 on the assurance of his 1919 net accumulation of wealth, how long would it require to pay for the farm and its equipment? Assuming interest on farm indebtedness to be $5\frac{1}{2}$ per cent and that the rent paid as a renter equals interest on the total farm value, and assuming further that, as farm indebtedness is lessened, the resultant saving in interest is applied to the payment of principal, it would require the tenant nearly 28 years to pay completely for his farm and equipment from his \$291 annual accumulation of wealth. If the tenant were required to pay in cash at least one-third of the price of the farm and equipment before he could buy he would have to farm more than 13 years in order to complete payment.

³⁴ No wealth received from sources outside of the farm business, except for the labor done off the farm by the operator and his family, is included in these figures.

AGRICULTURAL HISTORY OF FARM OPERATORS.

TENURE HISTORY.

TENURE STAGES OF ALL OPERATORS.

Table 17 shows the percentage of all operators who passed through each of the several tenure stages or were engaged in other occupations, and the aggregate time spent in these stages since the operators began for themselves. These data show the relative importance of the different stages in the tenure history of the operators.

One-third of all the farm operators, as will be seen from Table 17, had been in other occupations than farming; but the per cent of aggregate years spent in other occupations was comparatively small, being 7.9 per cent of the aggregate time that all operators had been working for themselves.

Those entering other occupations generally fall into two classes: (1) Operators who had been fairly successful in other occupations and had followed them for a considerable number of years, and (2) operators who were not very successful as farmers and who voluntarily entered other occupations after having been farm operators or who were compelled to do so because of tenure reversals. Most of the men who have tried other occupations fall within the last class, and it is the influence of this class that makes the average age of entry to other occupations higher than the age of beginning as a farm hand and as a share tenant.

TABLE 17.—How the 368 operators have been employed since they began to work for themselves.

	In other occupations.	Farm hands.	Share croppers.	Share tenants.	Cash tenants.	Owners additional.	Owner operators.
Per cent of all operators who have been	32.5	51.8	41.0	85.8	7.4	10.6	35.1
Percent of aggregate years spent in each stage	7.9	14.2	10.6	43.8	.9	2.4	20.3
Average age of operators at time of first entering each stage.....	26	21	27	25	34	35	32
Average years spent in each stage.....	6	5	5	10	2	4	11

The farm-hand stage is used largely as a beginning stage for young unmarried men. The average age of entry into this stage was 21—less than the age of entry into any other stage, and 72 per cent of the total time spent in this stage was spent while the operators were single. However, share croppers, to a greater extent than any other tenure group, have been reversed to the hired-man stage, and have, consequently, spent more time after marriage in the farm hand stage than have the members of the other tenure groups.

The share-cropper stage is third in importance, considered from the standpoint of the number who have been in the stage, and fourth, considered from the standpoint of the per cent of time spent in it. The average age of entry into the stage is materially increased by the fact that 46 out of the 151 men who had at some time been croppers were croppers for the first time by reversal from a higher stage, entering the cropper stage at an average age of 32. The remaining 105 operators who had been croppers entered at an average age of 25, the same average age at which operators entered the share-tenant stage.

In point of number of operators involved and time spent in the stage the share-tenant stage has been by far the most important in the tenure history of the operators, nearly 86 per cent of them having been share tenants, spending thus 44 per cent of the aggregate time worked by all operators since they began farming for themselves. Operators who had been share tenants spent on an average 10 years each as share tenants, which was twice the time operators had farmed as croppers.

The data on the cash-tenant stage show how unimportant this stage has been in the tenure history of the individuals, since not quite 1 per cent of the aggregate time that operators had been working for themselves had been spent as cash tenants.

The owner-additional stage, also, had been used by but few operators, yet this stage is becoming increasingly important, and is already of much greater importance than the data would indicate. Of the 40 operators who have been owners additional, 32 have used the stage in the past 5 years, 3 used it from 5 to 10 years ago, and only 5 used it 10 years or more ago.

The important function of this stage is that of enabling the man who owns land to expand his business to fit his developing capacity as an operator when he can not find adjoining land for sale or does not have funds to buy it. Thirteen of the 26 operators who are now owners additional, and operate on an average 131 acres each, were formerly owner operators, farming an average of 85 acres, indicating that these men used the owner-additional stage to make a considerable expansion in the size of their operating unit.

The owner-operator stage is the tenure goal of practically all operators, and it is to be supposed that some have entered it and failed to maintain the status. Over one-third of all operators have been owner operators, but only about one-fifth of them are now in the stage. Thirty-two, or 24.8 per cent of the 129 operators who have been owner operators are now in some status below the owner additional status.

From the standpoint of total time spent in the stage by all operators, the owner-operator stage is second only to that of the share tenant.

Even at that, more than twice as much time was spent in the share-tenant stage as in the owner-operator stage. Operators had been in the owner-operator stage on an average longer than they had been in any other stage.

TENURE STAGES OF PRESENT TENURE GROUPS.

From the data presented in Table 18, showing the use of the different tenure stages by operators in each of the present tenure groups, it will be noted that owners and share tenants alike have made greater use of the farm-hand stage than they have of the cropper stage. This aversion to the cropper stage seems to be general in the black land; it is probably due to class discrimination against croppers, and to the close and sometimes disagreeable supervision given to them by the landlords.⁵⁵

It is to be hoped that these conditions can be remedied, for the cropper stage offers the inexperienced young man who has little capital a chance to get experience as an operator under the supervision of a successful farmer. It offers the further advantage of yielding a return over wages which is usually more than enough to cover the risk assumed by the new operator in the business.

It will be noted that 43.1 per cent of all croppers, as compared with only 12.8 per cent of all owners, have tried other occupations. This is evidence of the fact, noted elsewhere, that the unsuccessful operators have not stuck to farming as closely as have the more successful (see p. 46).

TABLE 18.—*Relative importance of different tenure and occupational stages in tenure history of operators, classified by present tenure of operators.*

Number of operators by present tenure.	Percentage distribution of operators by stages passed through, with average years in each stage.											
	Other occupations.		Farm hand.		Cropper.		Tenant.		Owner additional.		Owner operator.	
	P. ct.	Yrs.	P. ct.	Yrs.	P. ct.	Yrs.	P. ct.	Yrs.	P. ct.	Yrs.	P. ct.	Yrs.
65 croppers.....	43.1	6.9	72.3	7.1	100.0	6.5	49.2	5.1	(1)	-----	(1)	-----
194 tenants.....	24.5	6.4	48.3	4.9	32.7	4.4	100.0	11.5	3.6	2.6	14.0	4.6
109 owners.....	12.8	5.1	55.1	3.9	21.1	2.4	82.7	8.6	30.3	5.0	88.2	13.5

¹ Nine croppers have been owners or owners additional for an average of 5.2 years.

² Two examples will illustrate the popular prejudice against the cropper stage: One man whose sons were seeking to begin as farmers advised them to go to Dallas and seek employment, simply because they were unable to rent land except as croppers, his remark being, "If my boys have to farm like 'niggers' I don't want them to be farmers." Another case is that of a young man who had been a cropper on his mother in law's place for two years and had saved enough to buy farming equipment. He asked his mother-in-law for a share-tenant contract, and failing to get it from her he spent two weeks searching for a farm for rent to a share-tenant (this was in 1918), but failed to find a satisfactory place. He quit farming and began work as a barber, saying that if he couldn't be anything but a cropper he wouldn't farm at all.

The relative importance of the share-tenant stage is shown by the fact that the 109 owners had spent more time in the share-tenant stage than in the cropper and farm-hand stages and in other occupations combined. Furthermore, owners who received no fortuitous assistance in their tenure advance had been share tenants an aggregate of 4,876 years as compared with an aggregate of 2,183 years spent in other occupations in the farm-hand stages and the cropper stage combined.

More than half of all croppers, and 36 of the 194 share tenants, had attempted to operate in higher-tenure stages, but had failed in the attempt.

MOVEMENTS OF OPERATORS ON THE AGRICULTURAL LADDER.

If a man should climb the agricultural-tenure ladder by taking successively all the tenure steps that are found in the black land, he would pass through, in the order named, the following stages: farm-hand, share-cropper, share-tenant, cash-tenant, owner-additional, and owner-operator stages. However, only one of the 368 operators had taken all of these steps. For all practical purposes the tenure ladder in the black land may be given as follows: The farm-hand and cropper stages as the first step; the share-tenant stage as the next step; and the owner-operator and the owner-additional stages as the final step.

Very few operators climb the tenure ladder without interruption by reverses.³⁶ Twenty-six share tenants had never been in any other tenure stage, and had farmed for an average of 10.8 years each; 111 operators had been either croppers and share tenants or farm hands and tenants, but 56 of these had at one time or other been reversed in tenure, and 82 operators had taken all three tenure steps, 59 of these having had no tenure reversals. Thus only 16 per cent of all operators had climbed the agricultural ladder to the top without suffering some reverse in tenure status.

The proportions of all operators in each tenure class who had suffered tenure reverses were as follows: Croppers, 60 per cent; share tenants, 29.8 per cent; owners additional, 19.2 per cent; owner operators, 14.5 per cent. Economic pressure or failure caused 61.8 per cent of all reverses of croppers, 46.8 per cent of the reverses of share tenants, and 44.4 per cent of the reverses of owners. The different proportions of operators in each tenure who suffered reverses are largely due to the different proportions of operators of inferior ability in the different tenure classes. These differences in ability will

³⁶ A reverse here means a change from a higher to a lower tenure form unless such a change was accompanied by unmistakable evidence that the operator was better off financially by the change and made it of his own free will.

be more clearly shown in connection with the comparisons of the rates of accumulation of wealth by operators of the different tenure classes. In comparing these figures on reverses in the different tenure groups, it should be borne in mind that a tenure reverse from the owner stage is a more serious reverse than a reverse from the share-tenant stage, and that a reverse from the cropper stage is the least serious of all reverses.

WEALTH USED AND PROPORTION BORROWED AT TIME OPERATORS ENTERED EACH
TENURE STAGE.

Very little wealth was needed for operators to begin the share-cropper stage. In fact 20 of the 28 reporting had no wealth to begin with (Table 19). These 20 croppers doubtless were *half hands*, who depended entirely on labor performed for the landlord, and advances he made to them, for their living expenses during the year. The 8 croppers reporting wealth owned an average of \$380 and borrowed \$194, or about one-third of the total wealth used.

TABLE 19.—Average wealth used and amount borrowed at the beginning of the share cropper, share tenant, and owner stages, operators classified by present tenure.

Items classified by present tenure of operators.	Operators at beginning of cropper stage.		Operators at beginning of share-tenant stage.		Operators at beginning of owner stage.	
	Operators who owned wealth.	Operators who owned no wealth.	Operators who owned wealth.	Operators who owned no wealth.	Operators who owned wealth.	Operators who owned no wealth.
Share croppers:						
Number.....	8	20	21	15	6	1
Average wealth owned.....	\$380		\$287		\$1,167	
Average wealth borrowed ¹	\$194	\$77	\$284	\$149	\$1,908	\$720
Per cent wealth used that was borrowed.....	33.8		49.6		62.0	
Share tenants:						
Number.....			136	55	36	
Average wealth owned.....	(2)		\$525		\$2,436	
Average wealth borrowed ¹			\$415	\$282	\$3,910	
Per cent of wealth used that was borrowed.....			44.1		61.6	
Owners:						
Number.....			67	24	103	2
Average wealth owned.....	(2)		\$346		\$2,780	
Average wealth borrowed ¹			\$203	\$184	\$3,397	\$550
Per cent of wealth used that was borrowed.....			36.9		54.9	

¹ Borrowed wealth includes amount borrowed for operating and living expenses during the first year in the tenant stages, and wealth borrowed for these purposes and land debt during the first year of ownership.

² No data secured for share tenants and owners at time of beginning as a cropper.

It will be noted that over one-third of operators who are now croppers, and of operators who are share tenants and owners, owned no wealth when they began as share tenants. These operators either began on a very small scale or had concessions such as free use of teams, tools, etc., from kinfolk.

Of the operators who owned wealth on entering the share-tenant stage, those who are now croppers used the least wealth and borrowed the largest proportion and those who are now share tenants used the most wealth (an average of \$940).

The average amount of wealth used by all tenure classes on beginning as share tenants was \$787, and this was but slightly less than the average amount of wealth used by 43 operators who began the stage since 1909. It would seem, therefore, that this represents about the amount of wealth needed to begin the share-tenant stage before the rise of prices owing to the World War, the amount needed under war prices probably being at least 50 per cent more.

Owners borrowed a smaller proportion of the wealth they used than did either of the other two classes. From this fact it might be concluded that the less the operator borrows the more likely is he to succeed, a conclusion that in all probability is erroneous. These data, however, may suggest that the present credit facilities are at fault, and that the owners were possibly more judicious borrowers because of these faults.

Both the share croppers and share tenants who had tried the owner stage had borrowed almost two-thirds of the capital they used upon becoming owners, but the latter used almost twice as much capital as did the former. Share tenants and owners both used over \$6,000 on becoming owners, but owners borrowed \$513 less on an average than did share tenants.

The data given in Table 19 seem to indicate that under prevailing credit facilities purchasers of land are safe if their net worth is about half of the value of the farm bought. Loans for longer periods of time and at lower rates of interest than is now commonly paid, with arrangements permitting payments to be made on the amortization plan, would no doubt make it safe to increase to more than 50 per cent the proportion of borrowed capital in land purchases, thereby encouraging ownership.

TIME REQUIRED FOR OPERATORS TO ATTAIN THE SHARE TENANT AND OWNER STAGES DURING DIFFERENT DECADES.

One of the causes for the rapid growth of tenancy sometimes suggested by writers on the subject is the increasing price of land and equipment, especially the increasing price of land. As a result, it is claimed that young men starting out must work longer than they formerly did in order to accumulate enough to make their first payment on land.

The information collected on this subject from the 368 operators of the farms surveyed is summarized in Table 20. No operators were included in the table if they had received as much as \$200 from

fortuitous sources before attaining tenancy or as much as \$500 before becoming owners.

TABLE 20.—Time required during different decades to attain the share tenant and owner stages, and the amounts of wealth used on beginning each stage, for operators who have received no fortuitous assistance.¹

Decade.	Conditions under which operators who are now tenants or owners attained tenancy.				Conditions under which operators who are now owners attained ownership.			
	Number of operators.	Years to attain tenancy.	Average wealth used when beginning as a tenant.	Per cent of wealth borrowed.	Number of operators.	Years to attain ownership.	Average wealth used when beginning as owner.	Per cent of wealth borrowed.
Before 1889.....	42	7.1	\$424	52.6	17	16.1	\$6 141	49.2
1889-1899.....	51	4.9	564	46.2	18	13.0	5,463	59.7
1899-1909.....	56	2.2	794	58.1	16	9.4	6,804	62.8
1909-1919.....	43	1.3	788	52.9	3	4.3	6,317	72.6

¹ Any value of \$200 or more received by gift, inheritance, or marriage, before or at the time of becoming a share tenant was considered *fortuitous assistance to tenancy*, and any amount received thus, of \$500 value or more, before or at the time of becoming an owner, was considered *fortuitous assistance to ownership*.

These data on share tenants are for men whose sole reliance in financial advance has been their earnings, and since they attained tenancy each decade in a shorter time and owned more wealth at the time of becoming tenants, it follows that ability to accumulate wealth had increased each decade, this increase, no doubt, being primarily due to an increased earning power.

The data on owners are not based on sufficient numbers to be conclusive, but the fact that they show the same tendency that is shown in the case of tenants is presumptive evidence of reliability.

With each decade, from the time prior to 1889, the total value of the farm has changed but little, which means that the size of the purchased farm has been reduced each decade. But there was a tendency to borrow a greater proportion of the wealth used with each succeeding decade, which would itself tend to shorten the time required to attain the owner stage. However, there is a difference of 6.7 years in the time required to attain the owner stage prior to 1889, as compared with the decade between 1899 and 1909, while the increased amount borrowed is only \$1,251, which could not account for the entire decrease of 6.7 years. Therefore, these data would indicate that in these groups, also, increased ability to accumulate wealth has shortened the time required to attain the owner stage.

SPECIAL CONDITIONS AFFECTING THE INDIVIDUAL'S TENURE STATUS.

One of the most important special conditions affecting the individual's tenure status is the receipt of wealth from fortuitous sources—inheritance, gift, or marriage. There were in all 50 owners who had received \$500 or more from fortuitous sources either at the

time or before they became owners. The average wealth thus received was \$3,578, and the operators receiving it attained the owner stage an average of 3.6 years sooner than did the owners who received no fortuitous wealth. In other words, each \$1,000 received fortuitously shortened by about 1 year the average time required to attain ownership.

It is interesting to note that owners receiving fortuitous help shunned the cropper stage and made use of the farm-hand stage more than did those who received no fortuitous assistance. The number of operators who had been farm hands, in the group receiving fortuitous help, was 3.6 times as many as the number who had been croppers. On the other hand, of the group receiving no fortuitous assistance, only 1.8 times as many had been farm hands as had been croppers. Operators receiving fortuitous assistance and who had been farm hands spent an average time of 5.4 years in the stage as compared with an average of 4.6 years spent by those receiving no fortuitous assistance, while of the operators who had been croppers, those receiving fortuitous assistance were croppers for an average period of 1.8 years, and those receiving no fortuitous assistance were croppers for an average of 2.6 years.

Calculations on the effects of receipts of fortuitous wealth on the time required to reach share tenancy³⁷ showed that for each \$703 received fortuitously before, or at the time of attaining tenancy, the average time of attaining the stage was shortened by one year.

About 89 per cent of all land owned was purchased by the owners, and the remainder was received in about equal amounts through marriage and inheritance. The proportion of all land owned that was received in these three ways are approximately the same for tenants and owners. The tendency for inheritance to break down the size of holdings is suggested by the fact that the average inherited farm was 65.5 acres in size, while the average size of the purchased farm was 141.6 acres—more than twice that of the inherited farm.

In order to determine whether or not there is any relation between the tenure of father and that of the son, data on the tenure status of the fathers of operators were taken. It was found that of the fathers who were farmers, 38.6 per cent of those of croppers, 68.2 per cent of the fathers of tenants and 75 per cent of those of owners were owners. From general observation, while interviewing operators, it is believed that the greater financial encouragement and assistance given by fathers who were owners was a more important influence in this regard than was the training and inherited traits of the operators whose fathers were owners. Nevertheless, it will be noted from Table 21 that there is a relation

³⁷ Only amounts of \$200 or more are considered fortuitous assistance to attaining tenancy.

between the tenure and the education of the operator, croppers as a class having less education than share tenants had, and share tenants having less as a class than had owners. However, it should not be inferred from the data presented in the table that the relation is all due to the effects of education on tenure.

TABLE 21.—*Relation between tenure and the education of the operator.*

Tenure group.	Extent of educational attainment.					
	Below fourth grade.		Fourth to ninth grade, inclusive.		Above ninth grade.	
	<i>Number.</i>	<i>Per cent.</i>	<i>Number.</i>	<i>Per cent.</i>	<i>Number.</i>	<i>Per cent.</i>
Share croppers.....	21	32.3	40	61.5	4	06.2
Share tenants.....	37	19.1	134	69.1	23	11.8
Owners.....	17	15.6	80	73.4	12	11.0

FINANCIAL HISTORY OF OPERATORS.

NET WORTH OF OPERATORS AND ITS SOURCES.

The wealth of the operator and the rate at which he accumulates it are better indications than tenure status of the operator's progress in agriculture. However, it is a well-known fact that financial and tenure progress generally develop together. This fact is brought out by Table 22, which gives the present net worth of the operator and the sources of his wealth. Owner operators, it will be noted, whose average present net worth was \$32,901, had almost 38 times as much wealth as croppers who owned on an average \$868.

Of the total net worth of all operators, 53.5 per cent came from net accumulations from earnings, 39.6 per cent from increases in land values, and 6.9 per cent from fortuitous sources.³⁸

Owners accumulated from their earnings an aggregate of 1.7 times as much as owners additional accumulated, 5 times as much as have tenants, and 21.2 times as much as have croppers. These differences in rate of accumulation from earnings by the different tenure groups are more significant when considered in connection with the average number of years the operators of the different tenure classes have been working for themselves. On this basis owners had an average annual accumulation from their earnings 1.3 times that of owners additional, 3.4 times that of tenants, and 15.3 times that of croppers.

It is obviously impossible to ascertain how much of the wealth received from increases in land values is attributable to the owner's superior judgment in securing and holding possession of the land and how much of it should be credited to things wholly outside the

³⁸ For a statement of what is included in the concepts of *net accumulation from earnings, increases in land values, and fortuitous wealth*, see footnotes under Table 22.

owner's efforts and ability. If such a separation were possible, a figure on *accumulation from all human efforts*, mental and physical, would show much greater differences for the operators than are shown by the comparisons made in the above paragraph.

TABLE 22.—Average present net worth per operator and its sources, by tenure classes.

Present tenure status.	Number of operators.	Average present net worth per operator.	Average amount of wealth accumulated from earnings. ¹	Wealth received from increases in land values. ²		Wealth received from fortuitous sources. ³	
				Number of operators receiving.	Average amount received.	Number of operators receiving.	Average amount received.
Share croppers.....	65	\$868	\$721	5	\$732	15	\$444
Share tenants.....	192	3,979	3,047	34	3,014	91	840
Owners additional.....	26	16,166	8,761	26	5,981	14	2,645
Owner operators.....	83	32,901	15,254	83	15,807	53	2,882
All operators.....	366	10,851	5,822	148	10,632	173	1,577

¹ This figure does not include wealth received from increases in land values and fortuitous wealth, but does include any wealth made by the use of capital from these sources. *Accumulations from earnings* represent approximately the wealth the operator has earned from his farming efforts (labor and management) and any wealth made from the use of capital from whatever source received.

² *Increases in land values*, as used in this bulletin, means net increases from this source, all value of improvements put on the land by the owner being deducted.

³ Wealth received through inheritance, gift, and marriage.

Every owner interviewed had made more money from changes in land values than he had lost. Forty-eight per cent of the total present net worth of owner operators and 37 per cent of the present net worth of owners additional was secured from increases in land values. Only 34 of the 192 share tenants and 5 of the 65 share croppers received wealth from increases in land values, and the average amounts thus received were very small in comparison with the amounts received by owners.

The wealth received from fortuitous sources was relatively small as compared with the wealth received from the other two sources. However, it should be noted that owners received larger amounts of wealth from this source than did tenants. Fifty of the 67 owners who received fortuitous wealth got \$500 or more at the time of becoming owners or before. It is very probable that most of these operators received their fortuitous wealth at a time in their financial history when it was relatively of great importance to them as a "boost."

VARIATION IN ACCUMULATIVE ABILITY OF OPERATORS AND ITS INFLUENCE ON TENURE.

The extent to which men differ in their ability to accumulate wealth from their earnings is brought out by Table 23 and Figure 5. It will

be noted from the table that by far the greater proportion of tenants have accumulated less than \$200 annually, and that the 19 owners

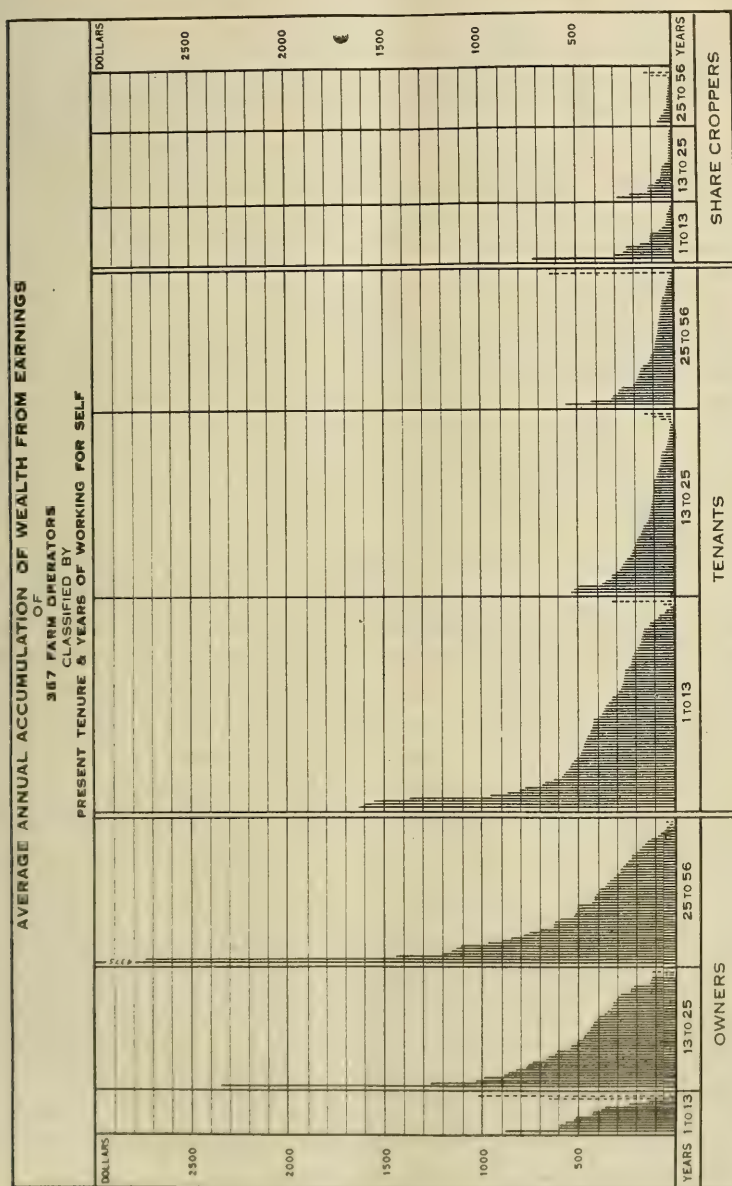


FIG. 5.—Average annual accumulation of wealth for 367 operators, classified by tenure.

in this class actually lost, on the average, instead of accumulating wealth from their earnings.

TABLE 23.—*Operators classified by tenure and by average amount accumulated from earnings annually.*

Operators whose net annual accumulation has been—	Share croppers.		Share tenants.		Owners.		All operators.	
	Number of operators.	Per cent of accumulation of all croppers.	Number of operators.	Per cent of accumulation of all share tenants.	Number of operators.	Per cent of accumulation of all owners.	Number of operators.	Per cent of accumulation of all operators.
Less than \$200.....	58	49.2	108	19.0	19	— 0.5	185	10.0
\$200 to \$400.....	6	34.8	45	27.4	29	15.3	80	21.3
\$400 to \$600.....			27	28.8	29	24.5	56	25.3
\$600 to \$800.....	1	16.0	4	6.0	14	16.8	19	12.1
\$800 to \$1,000.....			3	5.7	8	12.6	11	9.1
\$1,000 or more.....			4	13.2	10	31.3	14	22.2

It will be noted, furthermore, that 136 of the operators fall within the groups of farmers who saved \$200 and less than \$600. These operators, who are 37.1 per cent of all operators, and who save 46.6 per cent of the aggregate annual accumulation of all operators, are, in the main, what might be called consistent accumulators of wealth. They are not outstanding accumulators, on the other hand, nor are they failures.

From Figure 5 it is evident that there is a very great range between the two extremes, that of the few high accumulators, and that of the large number of low accumulators. This point is illustrated concretely by the fact that the best 14 accumulators, whose average annual accumulation from earnings was \$1,000 or more, saved annually \$23,940, as compared with an annual accumulation of \$24,105 by 238 who were the poorest accumulators. In other words, 14, or 3.8 per cent of all operators, accumulated annually about as much as 238, or 64.8 per cent of the 367 operators. The former saved 22.2 per cent of the aggregate annual accumulation of all operators; the latter, 22.4 per cent.

These facts concerning the extent to which men differ in ability to accumulate wealth from their earnings are fundamental in the tenure problem. The most important thing brought out by them is the dual function of the different stages of tenancy. Not only do these different stages function as stepping-stones to the rising operator, but they function also as selective agencies, often reversing the operator of inferior ability into the lower stages, or else keeping him there, where he is subject to the supervision of an operator of proved efficiency and capacity.

This dual functioning of the different stages of tenancy is strikingly shown in Figure 5. The best accumulators of the two tenant classes are the men who have worked for themselves the shortest time; while the poorest accumulators are those who have worked for them-

selves longest. In other words, figuratively speaking, the operators of greatest capacity and efficiency (which undoubtedly are the main determinants of largest accumulating power) crowd upper strata of the tenant stages and soon pass off into the owner stage. On the other hand, the poorest accumulators of the owner and share-tenant stages suffer reverses and settle toward lower stages, out of which some never rise.

Among owners, however, the majority of best accumulators have worked for themselves longest—the reverse of the situation with the tenant classes. Many operators become owners through fortuitous assistance and often can remain in the stage throughout life, even though suffering a small annual loss. Nevertheless, reversals from this stage (there were 42 tenants out of the 258 who had at one time been owners) largely involve incompetent operators, many of whom can provide for their families best in a state of tenancy, where they are supervised by more competent operators.

These two functions of the different tenure stages are based on the fundamental fact that men vary greatly in ability to produce and accumulate, which fact must not be neglected in shaping any land policy. It is highly important that the road to advanced stages be kept open and free from uneconomic handicaps, such as speculative land values; that care be taken that the operators in the lower stages get a return commensurate to their efforts and ability; that they have proper houses to live in; that they be given a chance to expand as they prove their ability; and that they have contracts protecting them in their rights and protecting the landlord from any dishonesty on the part of unscrupulous renters.

CLASSIFICATION OF OPERATORS ACCORDING TO ABILITY TO ACCUMULATE WEALTH.

The reasons why men differ in their ability to accumulate wealth are numerous. In fact, each case probably has its own set of reasons that are somewhat different from all others. Nevertheless, there are some general conditions associated with the rate of accumulation which can well be brought out by way of comparison.³⁹

A glance at Figure 5, in the light of what has been said on the dual function of the tenure stages, will show that a tenure classification within itself is a rough classification of operators into classes of accumulators. However, within each tenure class there are good as well as poor accumulators; therefore operators within each tenure class were divided into the *best*, the *medium*, and the *poorest accumulators*.

³⁹ The factors that enter into the individual operator's ability to accumulate wealth from his earnings are as follows: (1) Ability to produce, which depends on the operator's capacity and efficiency; (2) ability to save wealth produced; and (3) ability to use saved wealth in the production of more wealth.

lators on the basis of the average annual accumulation of wealth from earnings.⁴⁰

Data presented in Table 24 indicate the reliability of the above classification of accumulators. It will be noted that the present net worth of the different classes of accumulators increases without exception in passing from the poorest to the best in all three tenure classes, increasing from an average net worth of \$187 for the poorest cropper accumulators to \$46,903 for the best owner accumulators. Furthermore, the 1919 net family accumulation increases from the poorest to the best without exception, in each of the tenure classes. The best accumulators from earnings also accumulated most from increases in land values, as would be expected.

TABLE 24.—Average present net worth, its sources, and the average family accumulation of wealth during 1919, for the different classes of accumulators.

Items of correlation.	Croppers.			Tenants.			Owners.		
	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.
Number of operators.....	21	19	22	65	62	64	39	31	34
Present net worth of operators.....	\$187	\$731	\$1,697	\$2,001	\$3,305	\$6,685	\$16,063	\$21,498	\$46,903
Average amount received from fortuitous sources ¹ ...	143	72	107	480	137	563	1,984	1,666	1,599
Average received from increases in land values ¹ ...	21	106	18	369	355	862	8,661	10,156	20,869
Average family accumulation of wealth for 1919 ² ...	-11	169	231	54	199	618	-178	862	977

¹ Averaged on all operators in class whether wealth was thus received or not.

² See item 10, Table 15.

RELATION BETWEEN SIZE AND VALUE OF FARM OPERATED AND ACCUMULATION OF WEALTH FROM EARNINGS.

It is quite definitely shown in Table 25 that the best accumulators in each tenure class are now on farms which have the largest value in land and buildings, the largest value in equipment, the greatest acreage, and largest number of work stock. Moreover, it will be seen that the best accumulators had generally operated the largest farms when they were in other tenure stages. On the other hand, the opposite condition is shown by data on the operators who were the poorest accumulators.

This close relation between the best accumulators and the largest and most valuable farms is not only the result of demonstrated effi-

⁴⁰ In making this division of operators it was recognized that accumulation of wealth is influenced by the age of the operator; also by the period of time in which the accumulation was being made. Consequently operators were first grouped by periods of time when they began for themselves and were then regrouped by age groups so as to eliminate as nearly as possible these two influences before the operators were divided into the above three classes of accumulators. After selecting the three classes of accumulators in the final groups, based on age of the operators, the best accumulators in each tenure class were brought together, as were the other two classes of accumulators.

ciency and capacity of the operators, but is also partly due to the superior *wealth saving and using ability* of the best accumulators.

In agriculture, development of ability and advance in one's vocation is more largely dependent on the amount of personally accumulated wealth than in many other vocations. The farmer must have capital, and this is usually owned, borrowed, and rented, or is owned and borrowed. The amount the farmer can borrow depends to a considerable extent on his wealth, much of which is, as a rule, secured from accumulations from earnings. But wage hands, skilled mechanics, professional men, and men employed in numerous corporate industries can, and frequently do, rise in their vocations, whether they save from their earnings or not. Saving from earnings for the farmer is, therefore, not only one of the most important factors in accumulation of wealth, but it is also a means to the expansion of his business and to the fuller development and employment of his ability as an operator.

TABLE 25.—*Relation between different classes of accumulators of wealth and the size of the farm business in 1919, and average size of farm operated under the different tenure stages of the operator's history.*

Items of correlation.	Croppers.			Tenants.			Owners.		
	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.
Number of operators.....	21	19	22	65	62	64	39	31	38
Average value of land and buildings operated in 1919.	\$6,805	\$7,158	\$15,399	\$13,657	\$15,332	\$19,028	\$14,571	\$18,891	\$26,248
Average value of equipment used in 1919.....	\$596	\$774	\$1,173	\$1,261	\$1,567	\$2,014	\$1,452	\$2,101	\$2,344
Average acres in crops in 1919.	37.9	45.8	79.9	85.9	88.0	106.9	81.1	107.2	136.7
Average number of work stock per operator in 1919.	1.9	2.7	2.8	3.7	3.9	4.8	3.9	4.5	6.1
Average acres operated when a cropper ¹	42.4	47.8	75.1	45.3	59.9	52.4	58.5	30.8	102.9
Average acres operated when a share tenant ¹	66.5	50.2	67.4	78.8	85.9	100.0	73.9	78.3	89.9
Average acres operated when an owner ¹	102.0	.....	55.5	94.7	83.0	87.5	100.1	116.1	168.1

¹ The number of operators in these three lines varies from the number given at the top of the tables in most cases the number being less.

RELATION BETWEEN THE OPERATOR'S DEGREE OF APPLICATION IN OPERATING HIS FARM AND HIS ACCUMULATION OF WEALTH FROM EARNINGS.

Constancy of purpose and application to the business of operating a farm has evidently been exercised more among the best accumulators than among the poorest. This fact can be seen by comparing the sets of data of almost any two classes of accumulators in Table 26, but the data on the two extreme classes will be used to bring out the point. In the case of owners the best accumulators have been working for themselves an average of 24.5 years, while the poorest accumulators among croppers have been working for themselves for an average of 19.4 years. The former

group have spent on an average only 2.1 years, or 8.6 per cent of the total time since they began for themselves in other occupations and as farm hands, while the latter group (the poorest cropper accumulators) have spent on an average 9.9 years, or 51 per cent of their total time, in other occupations and as farm hands. Put in another way, the best owner accumulators have applied themselves to operating a farm 91.4 per cent of the time since they began for themselves, while the poorest cropper accumulators have applied themselves only 49 per cent of their time.

The data showing the value of the labor done on the farm and off the farm show that in each tenure group the best accumulators did more work on the farm they operated and less work off the farm than the poorest accumulators. In other words, the best accumulators confined their efforts to their own farms more than did the poorest accumulators.

It is obviously impossible to say to what extent the lack of application to the farm business on the part of the poorest cropper accumulators is the cause of inability to accumulate or to what extent it is the result of it. However, it is very important to note that poorest accumulation and the least application to the farm business are closely associated, and that the greatest accumulation of wealth and the most application to the farm business are closely associated.

TABLE 26.—*Relation between accumulation of wealth and the application of the operator to his farm business.*

Item of correlation (average for each operator in the class).	Croppers.			Tenants.			Owners.		
	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.
Number of operators.....	21	19	22	65	62	64	39	31	38
Average present age.....	40	36	39	38	39	37	45	44	45
Average years as farm operators.....	9.5	9.5	11.5	13.3	14.1	13.1	21.2	19.0	22.4
Average years at other occupation ¹	3.0	2.8	3.4	1.9	1.4	1.2	0.3	0.7	0.3
Average years as farm laborer ¹	6.9	4.6	4.3	3.1	2.1	1.3	2.7	1.8	1.8
Per cent of total years since beginning for self spent in other occupations and as farm laborers.....	51.0	43.8	40.1	27.3	19.9	16.0	12.4	11.6	8.6
Average amount per operator received for labor done off farm, for year 1919.....	\$253	\$183	\$112	\$145	\$94	\$138	\$124	\$94	\$67
Average value of operator's labor on farm, 1919.....	\$324	\$292	\$393	\$425	\$494	\$456	\$468	\$491	\$543

¹ Averaged by all operators in group and not by actual number who were in other occupations or farm laborer stages.

RELATION BETWEEN DIVERSIFICATION OF FARM ENTERPRISES AND ACCUMULATION OF WEALTH.

It will be noted from Table 27 that the per cent of all crop land on the farm planted to cotton was highest in the group of poorest accumulators and smallest in the case of the best accumulators.

On the other hand, small grain was grown in the largest proportions to all crops by the best accumulators and in the smallest proportions by the poorest accumulators, in each of the three classes of tenure.

On farms where cotton is a large proportion of all crops there are seasons when practically the whole labor force and all equipment are idle. These same periods are usually times when teams, tools, and men can be employed profitably in small grain fields, and it is this use on the mixed grain and cotton farm of (what on the cotton farm would be) idle labor and equipment, that helps to swell the profits on the mixed grain and cotton farm. Furthermore, when several years of operation are considered, the risks from agriculture are much more uniformly distributed and probably made less by the mixed grain and cotton type, as against the one-crop type of agriculture.

It will also be noted that the greatest number of animal units other than work stock, the greatest number of poultry, and the greatest value of garden, fruit, poultry, and dairy products used for family and furnished by the farm are associated, without exception, with the best accumulators in all the tenure classes. On the other hand, in every case (except two) the smallest amounts of the items above mentioned are associated with the poorest accumulators in each tenure class.

TABLE 27.—*Relation between the diversification of farm enterprises and classes of accumulators.*

Items of correlation.	Croppers.			Tenants.			Owners.		
	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.	Poorest.	Medium.	Best.
Number of operators.....	21	19	22	65	62	64	39	31	38
Per cent of all crop land planted to cotton.....	90.8	83.9	69.8	72.1	66.6	64.2	59.5	65.8	56.4
Per cent of all crop land planted to small grain....	1.8	2.6	8.9	11.7	16.1	19.0	20.5	18.6	22.2
Average number of animal units other than work stock ¹	1.1	1.5	3.0	2.3	3.8	4.5	4.5	4.5	7.0
Average number of poultry per farm.....	18	26	43	50	66	66	67	64	77
Average value in dollars received from farm for family living from garden, fruit, poultry, and dairy products.....	135	205	269	314	369	375	408	457	493
Average value in dollars of groceries bought.....	355	329	278	279	281	317	286	292	290
Average value in dollars of clothing bought.....	155	182	274	255	260	293	322	330	423
Per cent of all operators who reported sickness in family during 1919.....	42.9	25.0	19.1	25.8	22.4	18.3	26.3	26.7	27.0
Per cent of all operators in class that used short time credit in 1919.....	81	100	77	94	82	72	82	81	53

¹ "Animal unit" assumed here is the equivalent of one horse, one cow, or 7 hogs or sheep. Poultry is not included.

There is little difference in the amounts spent for groceries by the different classes of accumulators, but there is a large difference in the value of food raised on the farm, the poorest cropper accumulators receiving an average of \$135 worth of food from the farm as compared with \$493 worth received by the best owner accumulators. Edibles raised on the farm apparently do not reduce family grocery bills appreciably, but they do raise the family dietary standards.

The extent of this increase in dietary standards from edibles raised on the farm is not adequately shown by a comparison of values, for the most important difference is due to the quality of the food rather than to its value in dollars, and it is not at all unlikely that the lower dietary standards of the poorest accumulators cause much of the larger amount of sickness found among them and indirectly influences accumulations. (See data on health in Table 27.) The somewhat high per cent of sickness reported among all classes of owners is no doubt due to the advanced age of several operators in this tenure class.

Advocates of diversification have claimed, with good reason, that increased diversification would remedy the credit situation, making it less imperative for the operator to resort to short-time credit for running expenses. The data on this point show that the proportion who used short-time credit in 1919 was greater with the poorest accumulators than with the best accumulators by 4 per cent for croppers, 22 per cent for share tenants, and 29 per cent for owners. Although these differences are not entirely attributable to differences in degree of diversification, the marked association of the greatest diversification with the least short-time credit used indicates that diversification lessens the need for short-time credit for consumption purposes among the two poorer groups of accumulators in all tenure classes.

RELATION BETWEEN THE SHIFTING OF OPERATORS FROM FARM TO FARM AND THE
ACCUMULATION OF WEALTH.

Tenants in the black land have little to attach them to a given farm from one year to another. Almost all farm enterprises are completed annually, the relatively unimportant enterprise of raising stock being the only one that lasts from one year to another. Even this enterprise as conducted in the black land can be transferred from one farm to another with little difficulty. Because of these conditions tenants move very often for little or no reason.

Similarly, landlords can change tenants with practically no inconvenience or financial loss. Tenants are often asked to move without knowing in what particular they have failed, or have displeased

their landlords. As a result, the connection between landlord and tenant, as a rule, is transitory, neither party being willing to continue the connection if either finds the least objection to it.

The average number of years between shifts from farm to farm for share croppers, share tenants, and owners is shown in Table 28. The poorest cropper accumulators moved on an average every 2.3 years, while the longest time between shifts was 7.6 years for the best owner accumulators. The average cropper has nothing but a few household goods and his family to move, consequently he is more of a transient than the share tenant who owns his farming equipment.

The most important thing to note in connection with frequency of moves is that the poorest accumulators in each tenure class are also the operators who have moved most frequently; and that the best accumulators have remained longest, on an average, on the farms they have operated. Although it would require a detailed study on the subject to establish the optimum number of years between shifts, it can be said from the data presented in the table that most tenants move more frequently than they should for their best financial interests.

Some interesting facts are brought out in connection with the reason given for each move. It will be noted that a higher per cent of all moves were for "good economic reasons" in the case of owners than in the case of croppers and share tenants. Furthermore, in all three tenure classes the percentage of moves for good economic reasons was higher for the best accumulators than for the poorest accumulators.

TABLE 28.—*Relation between the shifting of operators from farm to farm and the accumulation of wealth from earnings.*

Per cent of all shifts that were made because of—	Croppers.			Tenants.			Owners.		
	Poor-est.	Medi-um.	Best.	Poor-est.	Medi-um.	Best.	Poor-est.	Medi-um.	Best.
Number of operators.....	21	19	22	65	62	64	39	31	38
Good economic reasons or advance in status.....	45.5	44.4	56.7	59.6	66.7	64.7	75.7	80.0	84.9
Plausible social, educational, or health reasons.....	4.5	4.8	9.6	5.6	8.0	12.7	6.4	3.5	5.5
Financial pressure, or personal faults of operators....	21.2	25.4	9.6	13.3	10.9	7.3	4.3	5.9	6.9
Other reasons given which did not seem to justify a shift.....	9.1	17.5	2.4	6.9	2.0	1.3	1.4	1.2	0.0
Reasons which could not be classified, or no reason given.....	19.7	7.9	21.7	14.6	12.4	14.0	12.2	9.4	2.7
Average number of years between shifts.....	2.3	2.2	2.5	3.0	3.6	4.0	4.7	5.4	7.6

Moves for social, educational, or health reasons are relatively few. However, it is interesting to note that the best accumulators of both tenant classes moved for these reasons in a greater per cent of all cases than is true of the poorest accumulators in each class of tenants. This indicates that the best accumulators probably think more of social, educational, and family standards than do the classes of poorest tenant accumulators.

Financial pressure or personal faults of the operator caused a greater proportion of moves among the poorest accumulators than among the best of either of the tenant classes. Among owners, however, the opposite situation is noted, which is possibly owing to the fact that the best owner accumulators have much more valuable farms. They have probably taken heavier risks than the poorest owner accumulators have assumed and have been forced more frequently to move because of these risks.

The data on moves for economic reasons taken in conjunction with the time between moves are, in general, indicative of the degree of application of operators to the farm business. Considered thus, again it will be seen that those operators who have applied themselves most consistently to their farm business have been able to accumulate the most wealth (see p. 45).

DOMESTIC, SOCIAL, AND EDUCATIONAL CONDITIONS IN RELATION TO TENURE.

DWELLING, SIZE OF FAMILY, AND FAMILY HEALTH.

Housing conditions for the different tenure classes are summarized in Table 29. The average value of the dwelling was \$532 for croppers, \$731 for share tenants, \$1,335 for owners additional, and \$1,532 for owner operators. These values were taken during the winter of 1919-20 and are somewhat higher than prewar values, although not so high as general price levels would indicate.

A comparison of value alone is not likely to give an adequate idea of the difference prevailing between the housing conditions of owners and tenants. For example, the owner operator's house has an average value nearly three times that of the cropper's house, but the cropper's house has three-fourths as many rooms. Thus, the average disparity between the construction and repair of the two becomes more evident when considered in the light of comparative number of rooms. Not only is the average renter's house poor and flimsy in construction but it is usually kept in very poor repair. Practically all of the reports of "poor condition" are confined to the tenant classes (see Figs. 6 and 7).



FIG. 6.—Typical owner homes.

Above.—The operator began for himself in the black land 39 years ago, with no wealth of his own; owns 381 acres of fertile black land; has accumulated from his earnings an average of \$781 annually, since he began for himself; has been a farm operator all the time, moving only twice.

Below.—The operator began for himself in the black land 29 years ago; owns now 153 acres of the best black land; has accumulated annually from his earnings an average of \$508; has moved 5 times since he began farming. Compare yards with the tenant yards shown on following page.

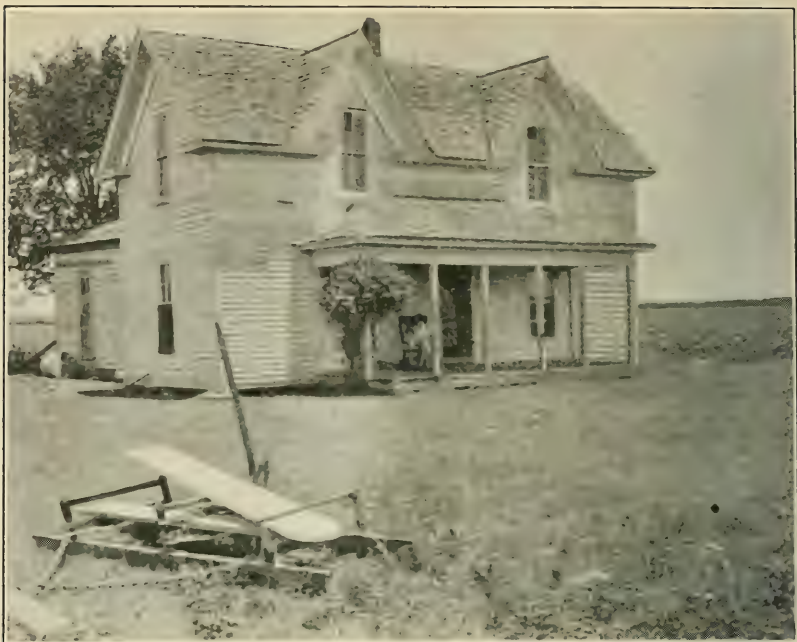


FIG. 7.—Typical tenant homes.

Above.—The operator is a "third and fourth share" tenant, beginning for himself in the black land 10 years ago; worked as a carpenter 3 years; has never moved since beginning to farm; has accumulated from earnings an average of \$83 per year. The land on this farm is among the most fertile in the black land. Note that crops are grown to the very door—a common situation on tenant farms in the black land.

Below.—The operator, a share cropper, began for himself 24 years ago in Tennessee and farmed in that State 10 years as a cropper, moving 5 times; he has moved 8 times and has had 4 reverses in tenure during the 14 years he has been in the black land; he attained the share tenancy stage and remained in it for 1 year only. Eleven people, including a married son and wife, live in the house. The operator has lost an average of \$4 per year since he began for himself 24 years ago.

It will be noted that there is no great difference in the average number of persons per room for all tenure classes. In all probability overcrowding is not the cause of much of the sickness found among these people, for the open construction of the houses would, in practically all cases where crowded conditions exist, provide for plenty of fresh air.

TABLE 29.—*Value and size of dwelling, size of family, and family health, by tenure classes.*

Tenure class.	The dwelling and its condition.					Size of family and family health.				
	Average value of house.	Average number of rooms in dwelling.	Number reporting condition of house as—			Average number in family.	Average number of persons per room.	Number reporting good health.	Number reporting poor health in family.	Per cent reporting poor health.
			Good.	Medium.	Poor.					
Share cropper.....	\$532	3.9	16	13	36	5.0	1.4	43	17	28.3
Share tenant.....	731	4.3	63	53	147	5.0	1.2	147	35	19.2
Owners additional..	1,335	5.0	8	3	15	4.9	1.0	20	6	23.1
Owner operators....	1,532	5.4	59	17	7	5.6	1.1	54	28	34.1

It will be noted that the percentage of reported sickness is higher for croppers than it is for tenants or owners additional. Doubtless this is due in large part to the fact that croppers lack the fresh, home-grown foods that the other classes have. Also, it is very doubtful if croppers have as much knowledge of sanitation and dietetics as do the other tenure classes. The highest per cent of reported sickness is found among owners, which is probably due to the much larger proportion among this class who are of advanced age.

RELATIVE STANDARD OF LIVING OF DIFFERENT TENURE CLASSES AS REFLECTED IN COST OF FAMILY LIVING.

The relative standards of living of the different tenure classes is probably better indicated by the total cost of family living than by any other available figure (see Table 30). The living cost of the average cropper family was 55 per cent, and of the average share-tenants family 71 per cent of the average cost of family living for owners. In making this comparison it is well to bear in mind that the average size of family for the different tenure classes was approximately the same.

The differences in standards as indicated by these data are not shown to the fullest extent; for the quality of food, the difference in the knowledge and practice of selection, preparation, and use of articles of food make the variations in standards much wider than are here indicated, especially between croppers and the other two classes.

Share tenants receive from the farm (in garden, dairy, poultry, and pork products) a value that is about 75 per cent as much as owners

thus receive, while croppers receive only 41 per cent as much value from these sources as owners. The most striking lack of these articles is, therefore, found with croppers.

TABLE 30.—Average cost of all family living, and of selected items of expense, for 368 operators.

Tenure class.	Average value per family.								
	All family living expenses.	All furnished by farm.	Meat, garden, poultry, and dairy products from farm.	All purchased.	Groceries purchased.	Clothing purchased.	Given to church and charity.	Spent for recreation, entertainment, etc.	Spent for tobacco and other personal expenses.
Share croppers.....	\$965	\$262	\$184	\$704	\$310	\$201	\$13	\$11	\$20
Share tenants.....	1,243	424	338	824	296	259	22	10	20
Owners.....	1,742	575	450	1,167	294	358	53	15	27

An interesting fact brought out in connection with the data on value of groceries purchased is that croppers, with the lowest standard of living, buy the most groceries; while owners who have decidedly the highest standard of living, buy the smallest amount of groceries, notwithstanding the fact that they have the largest families. The edibles from the farm for share tenants and owners supplement their groceries sufficiently to maintain about the same differences in values of foods that are found in clothing values.

The usual diet of operators who do not cultivate gardens and raise fresh meats consists almost entirely of groceries bought at local stores, few of which handle fresh vegetables and fruits. As a result, these important constituents of a well-balanced diet are often wanting in the meals of those who do not have gardens. Furthermore, good milk is relatively hard to buy in many localities. It is the lack of these important articles of food, or their inferior quality when bought, that makes the money value of family living an inadequate measure of the difference in family living standards.

The amount given to church and charity by owners is relatively large. Indeed, the difference in this regard is more marked than in any of the other items of expense.

The average amounts spent for recreation and entertainment is strikingly small for all classes. Few families of any tenure class take vacations, and but few more patronize "movies," theaters, or other entertainments that charge an admission fee. It is interesting to note in this connection that more is spent for tobacco and other personal expenses than is spent for recreation and entertainment. Picnics, fishing trips, pecan hunts, young folks' parties and dances, and school entertainments go to make up the principal entertainments

of the people. The Bohemians and people of other foreign extraction get much entertainment and amusement from public dances.

THE USE OF THE AUTOMOBILE, TELEPHONE, AND R. F. D. BY THE DIFFERENT TENURE CLASSES.

The automobile, the telephone, and the rural free delivery have done a great deal to make life on the farm more enjoyable, and at the same time have been a source of farm profit as well. Table 31 shows the extent to which these agencies are used by the different tenure classes.

TABLE 31.—Number and per cent of operators in each tenure class that have automobiles, telephones, and rural free delivery.

Tenure status.	Automobile.		Telephone.		Rural free delivery.	
	Number reporting.	Per cent having automobiles.	Number reporting.	Per cent having telephones.	Number reporting.	Per cent using R. F. D.
Share croppers.....	61	16.4	65	20.0	65	86.0
Share tenants.....	194	45.9	192	47.4	192	85.0
Owners additional.....	26	80.8	26	69.2	26	96.0
Owner operators.....	82	74.4	83	59.0	81	90.5

Automobiles are used less by croppers than by any other tenure class, about 1 in 6 having cars. Almost 1 out of every 2 share tenants owned an automobile; 4 out of each 5 owners additional, and 3 out of each 4 owner operators owned cars. Sixty owners estimated that on an average 34.3 per cent of the total use made of their automobiles was for farm business; 120 tenants estimated that on an average 37.2 per cent of the total use of their automobiles was for farm business. Forty of the 99 tenants who owned cars paid more on them for running expenses alone in 1919 than their entire family savings for the year amounted to.

The cost of the telephone is relatively small as compared with the cost of keeping an automobile, and there are probably few farmers who had telephones that did not make use of their telephones enough in their farm business to pay for the cost. About 1 out of every 5 croppers, almost half of the share tenants, 7 out of each 10 owners additional, and 6 out of each 10 owner operators had telephones.

Postal free delivery service was utilized by 86 per cent of all share croppers, 85 per cent of all share tenants, and 96 and 91 per cent, respectively, of owners additional and owner operators. Owners' homes are probably more frequently found on the main highways than are tenants' homes, and since these are the roads on which R. F. D. routes most often pass, owners probably are more conveniently located with respect to this service than are tenants.

READING MATERIAL OF THE TENURE CLASSES.

The extent to which the different tenure classes have access to periodical literature is shown in Table 32. Excepting croppers, 39.1 per cent of whom had no periodical literature, practically no farmer's family was without some periodical. Moreover, this encouraging fact is made more bright by the nature of this literature, which in most cases was first-class reading material.

Daily newspapers from the larger cities and towns of the black land constitute the greatest source of reading material for farmers in the area. In all tenure classes there were taken about as many daily newspapers as any other class of literature given in the table; and this fact, coupled with the more frequent issue of dailies, easily places them in the first rank in amount of reading material furnished.

From the instructional standpoint agricultural journals occupy the next most important place in the reading material of farm operators. However, a close second to the agricultural journals are the magazines, which as a rule are issued monthly. A few periodicals printed in the State dominate these two classes, and their influence among farmers is very great. Over 75 per cent of the total receipts of periodical literature were Texas publications.

The time devoted to reading books is relatively small as compared with the time spent in reading periodical literature. No books whatever, excepting school books, were found in 39 per cent of all owners' homes, and in 36 per cent of all tenants' homes.

TABLE 32.—*Periodical reading material in the homes of the different tenure classes.*

Tenure class.	Daily papers.		Nonagricultural weekly papers.		Magazines.		Agricultural journals.		Operators who have no periodical literature.	
	Number reporting on question.	Per cent who had daily papers.	Number reporting on question.	Per cent who had weekly papers.	Number reporting on question.	Per cent who had magazines.	Number reporting on question.	Per cent who had agricultural journals.	Number reporting on question.	Per cent of all operators reporting.
Croppers.....	63	34.9	63	36.5	64	32.8	62	30.6	64	39.1
Tenants.....	185	57.8	183	60.7	186	45.7	184	51.6	186	4.3
Owners.....	106	67.9	103	62.2	105	53.3	105	59.0	106	0.0
All operators.....	354	50.8	349	56.7	355	45.6	351	50.1	356	9.0

RELATION BETWEEN TENURE AND EDUCATION.

In order to ascertain facts as to the relation between tenure and education in the black land, data were taken from the teachers'

record books of five representative black-land schools, supplemented by data taken direct from teachers and pupils.⁴¹

It will be noted from Table 33 that the highest enrollment record for each month was made by the daughters of owners, and the lowest enrollment record for each month, except for April, was made by renters' sons. But monthly enrollment of the sons of owners was higher than it was for the daughters of renters.

It will be noted that the highest enrollment record for both the girls and boys of tenants was made in January. The first day of January is the beginning of the renting year so far as contracts are concerned, but few tenants get all their crops gathered until some time in January, and the majority of "moves" are made some time near the middle of the month. This means that tenants' children who are enrolled in school are in many cases enrolled in two schools at different times in January. Thus some of the children of outgoing renters as well as of incoming renters are enrolled in the same school for January, which accounts for the comparatively large enrollment of tenants' children during this month.

TABLE 33.—*Monthly enrollment, attendance, and change in make-up of school body as affected by tenure.*

I. PER CENT OF TOTAL YEAR'S ENROLLMENT REPORTED EACH MONTH.

Tenure of father and sex of child.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
Daughters of owners..	84.6	86.6	92.0	92.5	87.6	94.5	95.0	74.7
Daughters of tenants..	64.6	70.1	79.6	85.3	84.1	77.7	81.5	79.3
Sons of owners.....	85.2	87.6	93.3	91.0	84.3	90.0	83.8	75.7
Sons of tenants.....	59.6	64.6	78.6	82.1	74.1	72.9	82.7	75.0

II. PER CENT OF DAYS PRESENT TO AGGREGATE DAYS PUPILS WERE ENROLLED.

Daughters of owners..	89.5	85.9	84.2	83.7	88.2	90.6	92.1	93.0
Daughters of tenants..	81.4	79.3	79.1	78.0	83.3	83.4	85.4	88.1
Sons of owners.....	86.9	85.7	85.5	83.7	87.9	92.2	90.7	93.6
Sons of tenants.....	86.0	76.5	77.1	79.4	80.0	83.9	87.7	86.7

III. PER CENT OF ALL PUPILS WHO EITHER ENTERED OR WERE DROPPED FROM THE ROLLS EACH MONTH.

Daughters of owners..	78.6	9.5	7.5	9.5	6.0	2.0	7.5	1.0
Daughters of tenants..	60.5	14.7	14.0	14.6	14.4	9.5	13.6	6.5
Sons of owners.....	88.6	12.0	10.5	8.5	3.8	7.7	13.3	6.7
Sons of tenants.....	56.6	14.3	20.0	20.8	17.0	9.9	12.8	3.6

⁴¹ These schools were as follows: Florence Hill, a strictly consolidated rural school of 6 rooms, situated 6 miles in the country south of Grand Prairie, Dallas County; the Forrester School, a village school in Forrester, Ellis County; the Abbott School, a village school in Abbott, Hill County; Bell-Falls School, a 4-room rural school on the line of Bell and Falls Counties, 6 miles southeast of Troy, in Bell County; and the Macedonia School, a 2-teacher rural school, 5 miles southwest of Granger, in Williamson County, in a mixed American and Bohemian community.

The enrollment of tenants' children, both sons and daughters, shows a decidedly low stage during October, November, and December. This period is cotton-picking time, and tenants' children, as will be seen from a comparison of the data, stay out of school for cotton picking to a greater extent than do the children of owners. This low enrollment of tenants' children during cotton picking is due to the fact that tenants, as a rule, feel that they can not afford to hire their cotton picked, and to the fact that the landlords expect, and sometimes demand, that renters' children be put into the cotton fields in order to rush picking as much as possible.

Aside from the cotton-picking season, it will be noted that the enrollment of tenants' children is considerably less than the enrollment of owners' children during each of the other school months. This is in large measure the result of the fact that children of tenants who move into the school district are not enrolled in the first part of the school term, while those moving out are not enrolled during the latter part of the term. The situation of tenants' children in this regard is, therefore, not so bad as the percentages indicate. Nevertheless, the change of schools, teachers, and classmates in the middle of the year is bound to retard the educational advance of these children.

The daily attendance of the pupils enrolled during each month is much higher in the case of the children of owners than it is in the case of tenants' children. The record is lowest for all four classes of children during cotton-picking time, but is lower for tenants' children than for owners' children during this period.

During each month from November to March, from 14 to 20 per cent of all tenants' children who are in school during the year either enter school or drop out (Part III of Table 33).

The changes in membership of the classes in the schoolroom from month to month are much greater than the figures indicate, for these figures are based on the total enrollment for the year instead of the enrollment for the month. The change in the make-up of the enrollment of tenants' children is from two to three times as great for practically all months as it is for owners' children.

As a result of this shifting and fluctuating school enrollment and irregular attendance on the part of tenants' children, the showing which these children make in grade attainments and in promotions is poorer than the showing made by owners' children.

Referring to Table 34, showing percentages of promotions, it will be seen that there was a much smaller per cent of promotions among tenants' children than among owners' children. Of all

owners' daughters for whom reports were obtained, 96.5 per cent were promoted as compared with 77.2 per cent of tenants' daughters; while 88.6 per cent of owners' sons were promoted as compared with 65.6 per cent of tenants' sons. The same fact is brought out in an even more striking way by the percentages of the four groups that had been retained.

TABLE 34.—*Promotions of children of owners and of tenants.*

Tenure of father and sex of child.	Promoted.			Retained.			Not reporting.	
	Number.	Per cent of all in class.	Per cent of those reporting.	Number.	Per cent of all in class.	Per cent of those reporting.	Number.	Per cent of all in class.
Daughters of owners.	109	73.1	96.5	4	2.7	3.5	36	24.2
Daughters of tenants.	132	58.4	77.2	39	17.3	22.8	55	24.3
Sons of owners.	126	69.2	88.6	16	8.8	11.3	40	22.0
Sons of tenants.	103	43.3	65.6	54	22.7	34.4	81	34.0

If these conditions are general, they would indicate that the average tenants' child is more backward in school attainments than the average owners' child. That this is the case is indicated by Table 35, showing the average age and grade of the four groups of children. For the two groups of grades—the first four grades, and the fifth to eighth grades, inclusive—the tenants' children are from six months to a year older than the owners' children. In other words, the tenants' child is from six months to a year behind the owners' child in grade attainment. The data on pupils above the eighth grade do not show this same backwardness of tenants' as compared with owners' children. However, the numbers involved in this case are too small to make the data reliable.

TABLE 35.—*Average age of pupils in three groups of grades, classified by tenure status of father and by sex, for pupils in five black-land country schools.*

Tenure of father and sex of child.	Pupils in fourth grade and below.		Pupils in the fifth, sixth, seventh, and eighth grades.		Pupils in ninth grade and above.	
	Number.	Average age.	Number.	Average age.	Number.	Average age.
Daughters of owners.	93	8.6	77	12.6	16	15.3
Daughters of tenants.	169	9.3	113	13.5	11	14.4
Sons of owners.	106	8.9	92	13.3	20	16.4
Sons of tenants.	224	9.7	86	13.5	8	16.4

These unfavorable educational conditions associated with tenancy are, no doubt, not all attributable to tenancy. Tenants, as has been shown, are much poorer than owners; and this difference in the eco-

nomie status of the two classes causes tenants to draw more heavily on their children's time for farm labor than do owners. If the tenant were an owner, with his present wealth, he would doubtless still demand more field work of his child than the average owner now demands of his child. Consequently, it is impossible to say how much of the backwardness of the tenant's child is attributable to tenure and how much to financial status.

Regardless of this question, it is quite evident that the tenant's child is having to bear a heavier burden than is the owner's child. And it is evident that some of the more important rural school problems of the area are closely bound up with the problem of tenancy, and that they must be solved in conjunction with solutions of the tenure problem.

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BULLETIN No. 1069



Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C.



May 19, 1922

RELATION OF PRODUCTION TO INCOME FROM DAIRY COWS.

By J. C. McDOWELL, *Dairy Division.*

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PURPOSE OF THE WORK.

Large yields of milk and butterfat per cow are the aim of most dairymen and also of most breeders of dairy cattle. It is plain that the income from a farm dairy depends ultimately on the earning capacity of the individual units in the herd—the cows. The purpose of the work here reported is to analyze a large number of records and to show the relation between the productivity of cows and the income received by their owners. The records used are those of cow-testing associations.

Such an association, as ordinarily conducted in this country, is an organization of about 26 dairy farmers who cooperatively employ a man to test their cows for production of milk and butterfat. As the tester can ordinarily test only one herd a day, the 26 dairy herds furnish employment for each working day in the month. Records from a large number of cow-testing associations are a veritable mine of useful information. They cover a wide range of interesting dairy topics and show actual production under normal farm conditions.

For the purpose of this bulletin the records of individual cows from 96 cow-testing associations have been tabulated to show the relation of production to cost of feed and to income over cost of feed and

to ascertain the best methods of dairy-herd management. Some of the 96 associations furnished records for more than one year. In such cases the records for each year were tabulated as though they were from different associations. On that basis the 96 associations furnished 120 sets of records. Therefore, to determine from these figures the average number of cows on test in an association we must consider each set of records as a separate association.

In the 120 sets of records there were 2,939 herds and 41,990 cows on test. The study covered the period 1910 to 1920, inclusive; but every cow record was for a period of one year, the records of less than one year being included only when making herd and association summaries. In all other tabulations 12 months' records only were used.



FIG. 1.—Location of the 96 cow-testing associations whose records were tabulated.

It is well known that cows having high-production records are generally more profitable than those whose production records are not so high, and this bulletin shows the rate at which income over feed cost advances as average production increases.

CHARACTER OF DATA USED.

Figure 1 shows the distribution of the cow-testing associations whose records were tabulated:

So far as practicable the records of each association were studied independently of the others before being grouped into general tables. In this way any differences due to geographical location were noted and interpreted.

The first cow-testing association in the United States began work in Newaygo County, Mich., in 1906. On July 1, 1921, there were

452 active associations in the United States. The map (fig. 2) shows the location of these associations.

HOW THE RECORDS WERE STUDIED.

The individual cow record includes the name, breed, age, and weight of the cow. It also includes date of freshening, names of dam and sire, months in milk, pounds of milk produced, butterfat test, pounds of butterfat, price of product, total value of product, feed consumed, days on pasture, cost of pasture, cost of roughage, cost of grain, income over cost of feed, returns for \$1 expended for feed, feed cost per pound of butterfat, and feed cost per 100 pounds of milk.

In making the herd and association summaries here discussed the records of all cows on test 4 months or more were included. That is



FIG. 2.—Location of the 452 cow-testing associations in the United States, July 1, 1921.

the way such summaries are made by the testers in nearly all the cow-testing associations in the United States. In all other tabulations only the records of cows that were on test 12 consecutive months and had breed and age given were used. The reason for discarding the shorter records in making tabulations was to avoid possible error due to the use of such records. The possible error due to a use of such records, however, is probably negligible, as average yield, cost, and income proved to be about the same per cow-year¹ when the records of all cows on test were included as when only the records of those on test 12 months were included. (See Table 1.) This indicates that the herd and association summaries as now ob-

¹ See footnote to Table 1.

tained show about the same averages as they would if 12-months records only were used. The cows discarded before the end of the testing year were inferior cows, which would tend to lower average production, but they generally were on test during the early part of their lactation period, which would tend to increase average production. The figures shown in Table 1 indicate that these two influences nearly offset each other when large numbers of records are used.

This bulletin considers feeds chiefly from the standpoint of the income they produce over their cost but a study is now being made of the cow-testing-association records to determine the relation of feeds to other factors, in which feeds of various kinds are considered by quantity and feeding value.

GENERAL AVERAGES OF PRODUCTION, FEED COST, AND INCOME.

The figures in Table 1 are from the records of 120 sets of cow-testing-association records and they compare the 12-month records with all the records furnished by those associations. Tables 1 and 5 are the only tables in which anything but 12-month records are used.

TABLE 1.—*Comparison of the 12-month records with all the records studied—Averages per cow-year; period 1910 to 1920, inclusive.*

Item.	Cows on test 12 months and whose breed and age were given.	Cows on test 4 months and not more than 12 (includes first column).	Item.	Cows on test 12 months and whose breed and age were given.	Cows on test 4 months and not more than 12 (includes first column).
Number of cows.....	21, 234	41, 990	Cost of roughage.....	\$33. 41	\$32. 03
Number of cow-years ¹	21, 234	37, 362	Cost of grain.....	\$21. 89	\$21. 03
Average milk yield, pounds....	6, 077	5, 989	Total feed cost.....	\$55. 30	\$53. 06
Butterfat test, per cent.....	4. 08	4. 12	Income over feed cost.....	\$62. 70	\$59. 33
Average butterfat, pounds.....	248	247	Returns for \$1 expended for feed.....	\$2. 13	\$2. 11
Price of butterfat.....	\$0. 48	\$0. 46			
Value of product.....	\$118. 00	\$112. 39			

¹ A cow-year may be the record of 1 cow on test 12 months, or it may be made up of the records of 2 or more cows the sum of whose testing periods equals 12 months.

The average milk production per cow-year for the cows on test 12 months was 6,077 pounds, while the average milk production for all the cows on test was 5,989 pounds, a difference of only 88 pounds. The average production of butterfat per cow-year was 248 pounds for the cows on test 12 months and 247 pounds for all the cows on test, a difference of only 1 pound. In return for \$1 expended for feed there was a difference of only 2 cents per cow-year. For the cows on test 12 months the returns averaged \$2.13 and for all the cows on test the returns averaged \$2.11.

QUALITY OF COW-TESTING-ASSOCIATION COWS.

The estimated production per cow of all the dairy cows in the United States is approximately 4,000 pounds of milk and 160 pounds of butterfat a year. The records of association cows show them to be approximately 50 per cent above average in both milk and butterfat production, because the average production of those whose yearly records have been tabulated was 6,077 pounds of milk and 248 pounds of butterfat.

The greater yield of cows owned by association members is due to various causes, but is due chiefly to better feeding, breeding, and care.

RELATION OF BUTTERFAT PRODUCTION TO INCOME.

For Table 2 the records were sorted and grouped according to production of butterfat, each successive group center being 50 pounds above the one before it.

TABLE 2.—*Relation of butterfat production to income over cost of feed when the product was sold as butterfat; years 1910 to 1920, inclusive.*

Group No.	Number of cows.	Butterfat range.	Production average.	Average price of butterfat.	Average income over cost of feed.
		<i>Pounds.</i>	<i>Pounds.</i>		
1.....	4	0-25	23	\$0.38	1\$31.35
2.....	43	26-75	58	.41	113.88
3.....	600	76-125	109	.44	12.48
4.....	2,305	126-175	154	.44	27.90
5.....	4,310	176-225	202	.44	42.45
6.....	4,748	226-275	251	.44	57.82
7.....	3,385	276-325	298	.44	73.34
8.....	1,635	326-375	347	.44	89.67
9.....	652	376-425	396	.44	105.67
10.....	214	426-475	446	.45	124.85
11.....	79	476-525	493	.43	135.30
12.....	27	526-575	543	.40	134.80
13.....	8	576-625	600	.41	157.87
14.....	3	626-675	642	.43	150.62
15.....	1	676-725	708	.29	108.18
Total.....	18,014				
Average.....			248	.44	57.44

¹ LOSS.

The income from these 18,014 cows was obtained from the sale of butterfat. As the price received per pound varied little in the larger groups, the variation in income over cost of feed for those groups could not have been due to a difference in price of product. Evidently it was due to a difference in average production per cow, and this difference in production was due partly to the cows and partly to the way the cows were fed and cared for.

The group whose average yearly butterfat production was 154 pounds, or a little below that of the average dairy cow, had an average income of \$27.90 over cost of feed, while the group whose average

yearly butterfat production was 251 pounds, or about that of the average association cow, had an average income of \$57.82 over cost of feed, or more than twice as much. Income over cost of feed per cow is what remains for labor, miscellaneous expenses, and profits.

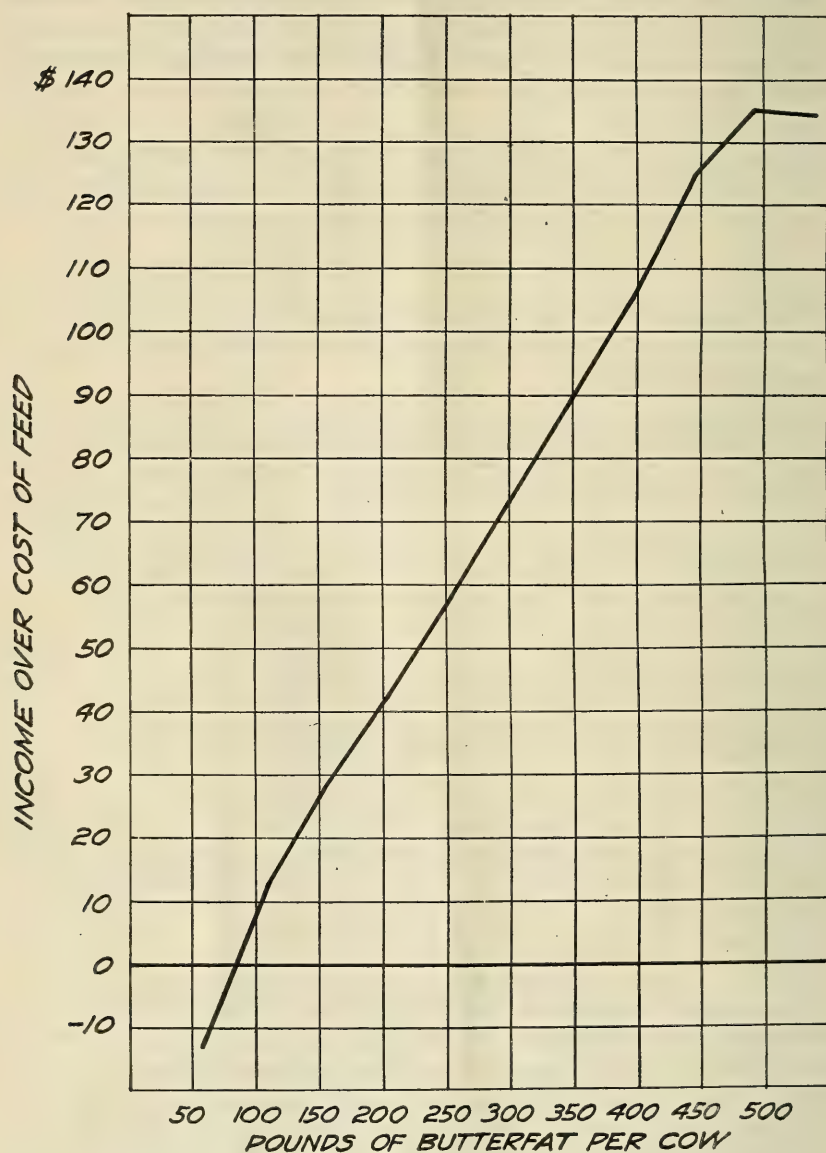


FIG. 3.—Relation between butterfat production and income over cost of feed.

Figure 3 shows in graphic form the relation of butterfat production to income over cost of feed as recorded for the larger groups in Table 2.

From this curve the income over cost of feed for each 50 pounds of gain in butterfat production may be determined. It is well known that dairy cows, to be profitable, must be comparatively large producers, yet few people fully realize the remarkable rate at which income over cost of feed advances as production increases. The chart shows that as average butterfat production increased from 150 to 200 pounds, the average income over cost of feed advanced from \$26 to \$42; that is, a gain of 50 pounds in butterfat production increased the income over cost of feed \$16, or nearly 62 per cent. The next gain of 50 pounds raised the income over cost of feed to \$58, the next to \$74, the next to \$90, and the next to \$106.

Briefly stated, as production of butterfat increased from 150 to 400 pounds, the income over cost of feed advanced from \$26 to \$106,



FIG. 4.—An Ayrshire herd in the Herndon (Va.) cow-testing association.

or exactly \$16 for each gain of 50 pounds in butterfat production. As butterfat production increased from 400 to 450 pounds the gain in income over cost of feed was about \$19. For the groups whose average production was above 450 pounds the income above feed cost was somewhat irregular, which may have been due to the fact that the number of records was too small to give dependable averages, or there may have been a point beyond which the cows did not respond so readily to more liberal feeding. Undoubtedly there is a point beyond which it does not pay to feed for increased production, but evidently that point is seldom passed in the feeding of cow-testing-association cows.

As prices of feeds and prices of dairy products rise and fall the income over cost of feed also may rise and fall, but a study of the

figures by districts and by years in the relation of production to income over cost of feed shows that any change for one group of cows was always accompanied by a similar change for each of the other groups. For that reason the curve shown in figure 3 may be considered as fairly representative for different years and for all sections of the country. It does not follow, however, that the income over cost of feed will always be \$26 for cows that produce 150 pounds of butterfat and \$106 for cows that produce 400 pounds of butterfat. The figures are relative, not absolute. The records were tabulated in many ways and always with the result that the groups of high-producing cows had a greatly increased average income over cost of feed as compared with the groups of low-producing cows. The figures showing the relation of butterfat to income gave much the same curve regardless of breed, age, weight, date of freshening, or geographical location.

Cow-testing-association records do not give labor costs and miscellaneous expenses, but they do show which cows are paying for their feed and which are not. In one herd, records of which were tabulated, the poorest cow produced in one year only enough income from butterfat over cost of feed to buy a 2-cent postage stamp. To pay labor costs and miscellaneous expenses the owner had the manure, skim milk, and the calf. With better cows and more intelligent feeding he would have had much more.

TWO HERDS COMPARED.

In the Cheshire (N. H.) cow-testing association for the testing year 1917-18 the herd that produced the most milk per cow was highest in average production of butterfat, highest in cost of feed per cow, and averaged next to the highest in income over cost of feed. For the same year in the same association the herd that produced the least milk per cow was lowest in average production of butterfat, lowest in average gross income, lacked 4 cents of being lowest in cost of feed per cow, and averaged lowest in income over cost of feed. The herd of greatest production per cow had an average income of \$212 over cost of feed, while the other herd had an average income of \$27 over cost of feed. It would require 78 cows like those in the inferior herd to produce as much income over cost of feed as 10 cows like those in the other.

BUTTERFAT AND COST OF FEED.

The figures in Table 3 are from the same tabulation as those given in Table 2, and they show the relation between butterfat production and cost of feed per cow.

TABLE 3.—*Relation of butterfat production to cost of feed when the product was sold as butterfat.*

Group No.	Number of cows.	Average butterfat production.	Average cost of feed.		
			Roughage.	Grain.	Total.
		<i>Pounds.</i>			
1.....	4	23	\$29.36	\$10.62	\$39.98
2.....	43	58	30.85	7.12	37.97
3.....	600	109	28.08	7.62	35.70
4.....	2,305	154	29.61	10.94	40.55
5.....	4,310	202	31.54	15.73	47.27
6.....	4,748	251	33.44	20.34	53.78
7.....	3,385	298	34.26	25.02	59.28
8.....	1,635	347	35.27	28.91	64.18
9.....	652	396	34.70	34.65	69.35
10.....	214	446	37.27	38.88	76.15
11.....	79	493	39.12	38.52	77.64
12.....	27	543	36.30	45.69	81.99
13.....	8	600	40.23	50.55	90.78
14.....	3	642	41.41	82.72	124.13
15.....	1	708	45.08	51.87	96.95
Total.....	18,014				
Average.....		248	32.75	20.12	52.87

These figures show only a moderate rise in cost of roughage as butterfat production increases, but they show a very rapid rise in cost of grain. The comparatively small difference in the cost of roughage per cow for the different groups may have been due partly to the feeding of the same quantity of roughage to all cows in the same herd, regardless of production. The increased cost of grain, however, was very regular as production increased. This was always true when the number of records in the group was great enough to furnish a fair average. Evidently many of the members of cow-testing associations

TABLE 4.—*Relation of butterfat production to returns for \$1 expended for feed and to feed cost per pound of butterfat where the product was sold as butterfat.*

Group No.	Number of cows.	Average butterfat production.	Average returns for \$1 expended for feed.	Average feed cost per pound of butterfat
		<i>Pounds.</i>		
1.....	4	23	\$0.22	\$1.758
2.....	43	58	.63	.648
3.....	600	109	1.35	.323
4.....	2,305	154	1.69	.264
5.....	4,310	202	1.90	.238
6.....	4,748	251	2.08	.214
7.....	3,385	298	2.24	.199
8.....	1,635	347	2.40	.185
9.....	652	396	2.52	.175
10.....	214	446	2.64	.171
11.....	79	493	2.74	.167
12.....	27	543	2.61	.151
13.....	8	600	2.74	.151
14.....	3	642	2.21	.193
15.....	1	708	2.12	.137
Total.....	18,014			
Average.....		248	2.09	.213

are feeding concentrates intelligently, according to known production. That, however, is not at all a general practice outside of the cow-testing associations.

RETURNS FOR \$1 EXPENDED FOR FEED.

The figures in Table 4, also taken from the same tabulation as those in Table 2, show the relation of butterfat production to returns for \$1 expended for feed, and to feed cost per pound of butterfat.

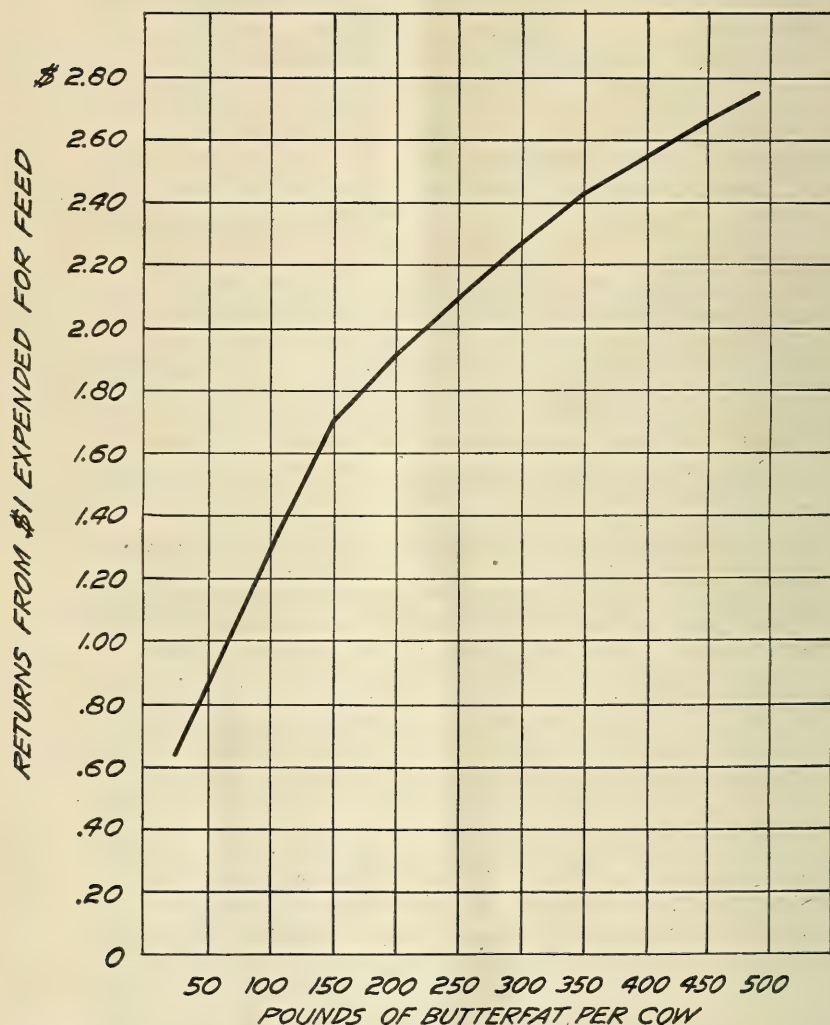


FIG. 5.—Relation between butterfat production per cow and the returns from \$1 expended for feed.

The returns for \$1 expended for feed increased quite regularly, and the feed cost per pound of butterfat decreased quite regularly

for each successive large group. As production increased from 109 pounds in the third group to 396 pounds in the ninth group, the returns for \$1 expended for feed increased from \$1.35 to \$2.52, or almost doubled. In Group 3 the returns were only 35 cents above the cost of the feed, while in Group 9 the returns were \$1.52 above the cost of the feed, or more than four times as much. It is also worthy of note that the feed cost per pound of butterfat was almost twice as high in Group 3 as in Group 9.

Figure 5 shows graphically for the larger groups the relation of butterfat production to returns for \$1 expended for feed as given in Table 4.



FIG. 6.—One of the highest-producing herds in the Carroll County (Md.) cow-testing association.

The curve shows that the returns for \$1 expended for feed increased at a very rapid rate as production of butterfat increased. The larger returns for feed in the groups having high average production were due to better cows and better feeding. The relative influence of these two factors can not be determined because the groups whose average production was high were always fed more liberally than those whose average production was lower.

Figure 7 shows graphically for the larger groups the relation between butterfat production and feed cost per pound of butterfat as given in Table 4.

The curve shows a very rapid decrease in feed cost per pound of butterfat as production increased from 58 pounds to 396 pounds. From that point on the feed cost per pound of butterfat decreased more slowly. The figures indicate that from the standpoint of feed cost alone the dairyman should give close attention to the improve-

ment of low producers or eliminate them. The figures from which curves were made cover the period 1910 to 1920, inclusive. When prices were high the curves had a slightly different position from what they had when prices were low, but always the curves followed the same general direction regardless of cost of feed or price of

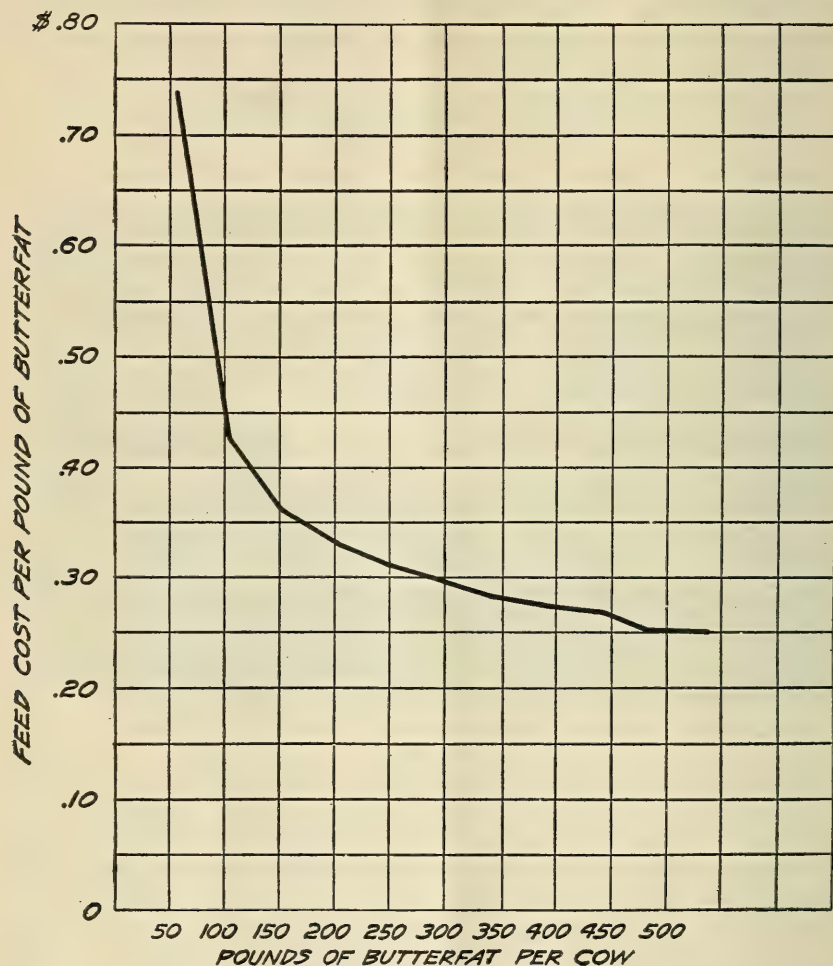


FIG. 7.—Relation between butterfat production per cow and feed cost per pound of butterfat.

product. Within the range of the large groups the high producers always won on income over cost of feed on returns for \$1 expended for feed and on low feed cost per pound of butterfat produced.

A STUDY OF HERD RECORDS.

To see whether a study of records by herds would give the same results as a study of individual cow records, a tabulation of the herd

records of many cow-testing associations was made, and is shown in Table 5. For comparative figures from individual cow records see Table 2.

The herd records were sorted according to average production of butterfat per herd, and the income over cost of feed was determined, as usual, by finding the weighted averages of the individual cow

TABLE 5.—*Relation of butterfat production to income over cost of feed as shown by a tabulation of the herd records of 1,309 herds where the product was sold as butterfat; years 1910 to 1920, inclusive.*

Group No.	Number of herds.	Number of cows.	Butterfat production.		Average income over cost of feed.
			Range.	Average.	
			Pounds.	Pounds.	
1.....	2	22	76-125	119	\$25.35
2.....	112	1,556	126-175	161	30.56
3.....	333	4,496	176-225	205	41.23
4.....	464	6,724	226-275	251	54.00
5.....	270	3,443	276-325	297	64.49
6.....	97	1,171	326-375	344	81.17
7.....	24	270	376-425	391	93.46
8.....	5	46	426-475	451	89.42
9.....	1	6	476-525	496	99.40
10.....	1	7	526-575	526	45.09
Total.....	1,309	17,741			
Average.....				248	52.84

records in each group. As there was no reason to believe that the tabulation of more records would materially affect final conclusions it seemed useless to carry this tabulation farther, though the number of records used in Table 5 was somewhat less than the number used in some of the other tables.

The increase in income over cost of feed as production increased is not quite so marked in Table 5 as in Table 2, because in the former the records were grouped according to herd averages regardless of individual production. Even with that handicap the high-producing herds always showed an increased income over feed cost as production increased from group to group. The average income over cost of feed per cow for the 24 herds in Group 7 was more than three times as great as for the 112 herds in Group 2.

CONCLUSIONS ALWAYS THE SAME.

Tabulations were made, by breeds, of thousands of records of grade and purebred cows to determine the relation of butterfat production to income over cost of feed. In every case the results were very similar to those already given. Tabulations for each age of each breed also gave similar results, and the results were about the same when the records for each association or for any agricultural district were tabulated. *It seems fair, therefore, to conclude that*

increased production is accompanied by increased income over cost of feed regardless of breed, age, weight, date of freshening, or geographical location.

PRICES AND PROFITS.

Several tabulations were made to determine, if possible, whether cows which were large producers of milk and butterfat are relatively more profitable or relatively less profitable when prices are high than when they are low. The results of such tabulations have so far been inconclusive, and for that reason the figures have been omitted. In every case of those studied, however, the low producers had a high feed cost per unit of production, low returns for \$1 expended for feed, and small income over cost of feed. In every case the high producers had a low feed cost per unit of production, large returns for \$1 expended for feed, and a high income over cost of feed.

RELATION OF MILK PRODUCTION TO INCOME.

MILK PRODUCTION AND INCOME OVER COST OF FEED.

Table 6 shows the relation of milk production to income over cost of feed in associations where the product was sold as whole milk. The results are much the same as those obtained from associations where the income was from the sale of butterfat.

TABLE 6.—*Relation of milk production to income over cost of feed when product was sold as whole milk; years 1915 to 1920, inclusive—From 3,220 yearly records.*

Group No. ¹	Number of records.	Milk production.		Average price of milk per 100 pounds.	Average income over cost of feed.
		Range.	Average.		
		<i>Pounds.</i>	<i>Pounds.</i>		
1.....	16	751- 2,250	1,662	\$2.56	\$3.47
2.....	223	2,251- 3,750	3,250	2.53	32.25
3.....	724	3,751- 5,250	4,605	2.53	59.58
4.....	927	5,251- 6,750	5,970	2.46	82.96
5.....	671	6,751- 8,250	7,429	2.40	105.36
6.....	371	8,251- 9,750	8,918	2.42	131.93
7.....	181	9,751-11,250	10,354	2.42	156.51
8.....	58	11,251-12,750	11,881	2.45	181.29
9.....	34	12,751-14,250	13,250	2.51	218.19
10.....	7	14,251-15,750	15,042	2.20	224.18
11.....	4	15,751-17,250	16,076	2.24	219.50
12.....	1	17,251-17,750	17,387	2.02	223.68
13.....	1	17,751-18,250	18,207	2.14	212.99
14.....	1	18,751-19,250	18,894	2.31	286.06
15.....	1	19,751-20,250	20,168	1.93	222.91
Total.....	3,220				
Average.....			6,575	2.45	92.11

¹ The records were sorted on the basis of milk production, allowing a difference of 1,500 pounds between group centers.

As milk production increased from Groups 1 to 9, there was a rapid and very constant increase in income over cost of feed. Beyond Group 9 the number of records in each group was small. In Group 1 the average production of milk was 1,662 pounds and the average income over cost of feed was \$3.47. In Group 9 the average milk production was 13,250 pounds and the average income over cost of feed was \$218.19. The milk production per cow in Group 9 was about 8 times as much as in Group 1, but the average income over cost of feed in Group 9 was about 62 times as great as in Group 1. This difference was not caused by increased price received for milk, as the average price of milk in Group 9 was lower than in Group 1. The price of milk, however, did not vary greatly within the larger groups.

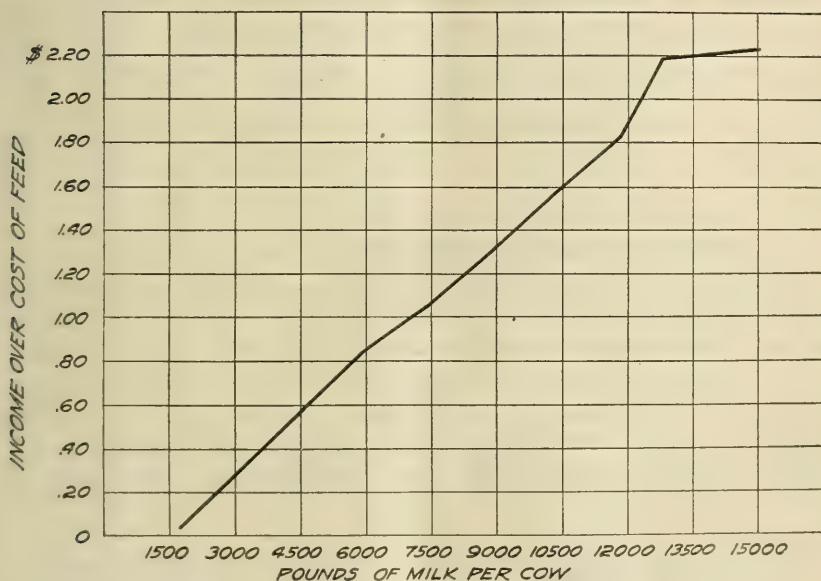


FIG. 8.—Relation between milk production and income over cost of feed.

Figure 8 shows the relation of milk production to income over cost of feed as given in Table 6.

This chart, which includes only the larger groups, is very similar to figure 3, which shows the relation of butterfat production to income over cost of feed. The line is very nearly straight. It shows not merely that large producers have a larger income over cost of feed than small producers, but it measures the increased income over cost of feed in dollars. *A herd of 62 cows like those in Group 1 would be required to produce as much income over cost of feed as was produced by the average cow in Group 9.*

MILK PRODUCTION AND COST OF FEED.

Table 7 shows the relation of milk production to cost of roughage, cost of grain, and total cost of feed. The table is a continuation of Table 6.

TABLE 7.—*Relation of milk production to cost of feed where the product was sold as whole milk.*

Group No.	Number of records.	Average milk production.	Average cost of feed.		
			Roughage.	Grain.	Total.
		<i>Pounds.</i>			
1.....	16	1,662	\$28.74	\$10.43	\$39.17
2.....	223	3,250	32.69	17.26	49.95
3.....	724	4,605	33.15	23.79	56.94
4.....	927	5,970	35.09	29.09	64.18
5.....	671	7,429	38.18	34.62	72.80
6.....	371	8,918	42.36	41.65	84.01
7.....	181	10,354	45.66	48.38	94.04
8.....	58	11,881	50.63	59.75	110.38
9.....	34	13,250	51.39	63.45	114.84
10.....	7	15,042	49.03	58.59	107.62
11.....	4	16,076	55.80	84.24	140.04
12.....	1	17,387	49.20	77.74	126.94
13.....	1	18,207	57.92	119.24	177.16
14.....	1	18,894	48.99	100.56	149.55
15.....	1	20,168	56.40	108.29	164.69
Total.....	3,220				
Average.....		6,575	37.06	31.81	68.87

This tabulation is similar to Table 3, in which the income was from the sale of butterfat, but Table 7 shows a more rapid increase in the cost of roughage for each successive group as milk production increased from Groups 1 to 9. The average cost of roughage was more than $1\frac{3}{4}$ times as high for Group 9 as for Group 1, the cost of grain was more than 6 times as high for Group 9 as for Group 1, and the total cost of feed was almost 3 times as high for Group 9 as for Group 1. Beyond Group 9 there were comparatively few records in each group.

TABLE 8.—*Relation of milk production to returns for \$1 expended for feed and to feed cost per 100 pounds of milk where product was sold as whole milk.*

Group No.	Number of records.	Average milk production.	Average returns for \$1 expended for feed.	Average feed cost per 100 pounds of milk.
		<i>Pounds.</i>		
1.....	16	1,662	\$1.09	\$2.36
2.....	223	3,250	1.64	1.54
3.....	724	4,605	2.05	1.24
4.....	927	5,970	2.29	1.07
5.....	671	7,429	2.45	.98
6.....	371	8,918	2.57	.94
7.....	181	10,354	2.66	.91
8.....	58	11,881	2.64	.93
9.....	34	13,250	2.90	.87
10.....	7	15,042	3.08	.72
11.....	4	16,076	2.57	.87
12.....	1	17,387	2.76	.73
13.....	1	18,207	2.20	.97
14.....	1	18,894	2.91	.79
15.....	1	20,168	2.35	.82
Total.....	3,220			
Average.....		6,575	2.34	1.05

RETURNS FOR \$1 EXPENDED FOR FEED.

The figures in Table 8 show the relation between milk production and returns for \$1 expended for feed and the relation between milk production and feed cost per 100 pounds of milk. This table is also a continuation of Table 6.

In Group 2 the average milk production was 3,250 pounds, and the average returns for \$1 expended for feed \$1.64. In Group 9 the average milk production was 13,250 pounds, and the average returns

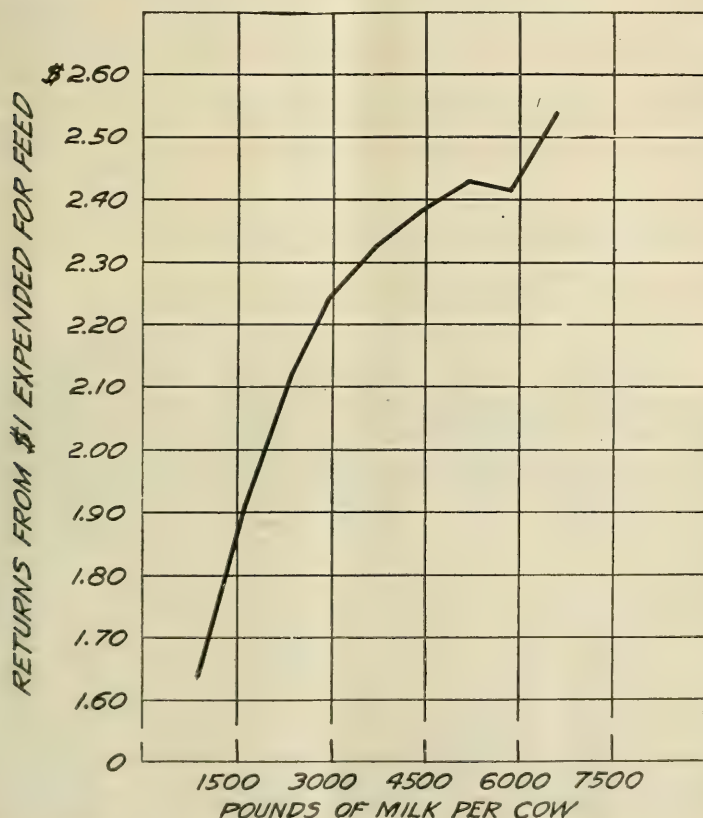


FIG. 9.—Relation between milk production and returns from \$1 expended for feed.

for \$1 expended for feed \$2.90. In Group 2 the average cost of feed for 100 pounds of milk was \$1.54, and in Group 9 only \$0.87.

Figure 9 shows graphically the relation of milk production to returns for \$1 expended for feed.

The figure shows that the returns for \$1 expended for feed increased rapidly though somewhat irregularly as milk production increased from Groups 1 to 9. The cows that averaged 12,000 pounds

of milk a year returned about 50 cents more from a dollar's worth of feed than was returned by the cows that averaged 6,000 pounds of milk a year.

Figure 10 shows the relation of milk production to feed cost per 100 pounds of milk.

As milk production increased from Groups 1 to 9 the feed cost per 100 pounds of milk decreased very rapidly at first and more slowly

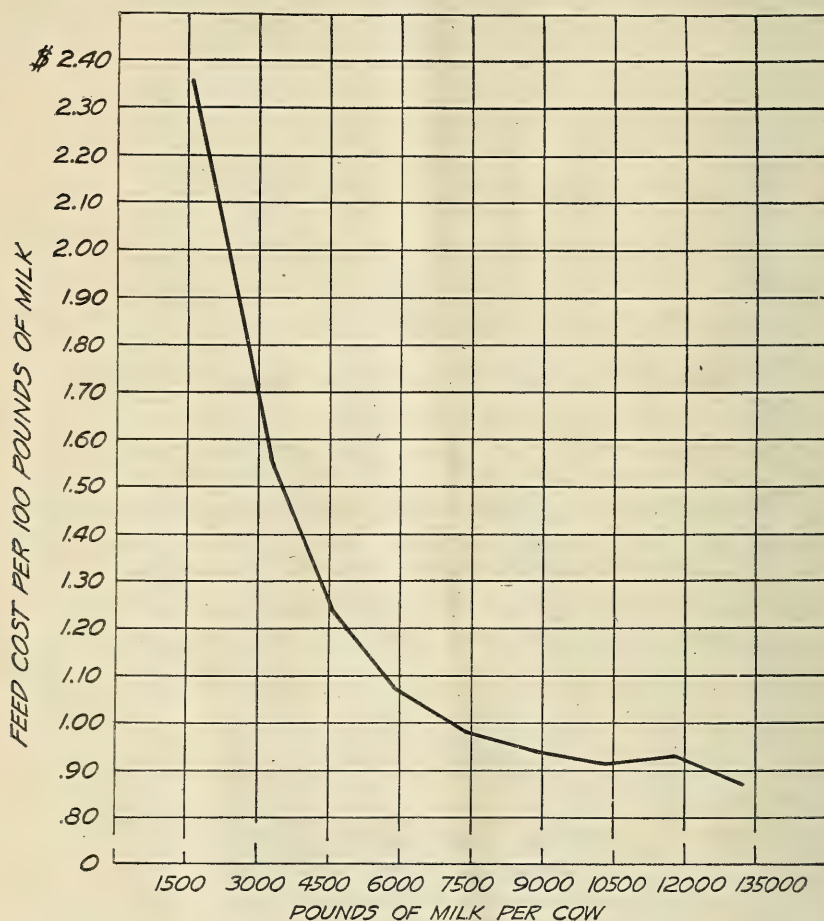


FIG. 10.—Relation of milk production to feed cost per 100 pounds of milk.

as production reached a high level. At current prices for feed the feed cost for each group would vary from the figures given, but recent records show that the direction of the curve would not be greatly changed.

The foregoing evidence, based on cow-testing-association records, shows definitely the greater earning power of high-producing cows

compared with the general average of herds and especially when compared with low producers, and the figures show the degree by which good cows surpass poor ones. Moreover, they throw additional light on the great usefulness and also on some of the limitations of cow-testing associations. The points may be summarized briefly as follows:

WHAT THE COW-TESTING ASSOCIATION CAN AND CAN NOT DO.

The cow-testing-association records take much of the guesswork out of dairying. Conformation indicates performance; but the Babcock test, the milk scales, and the feed scales tell the true story. Knowing the true feed and production records, the good dairyman practices selective breeding, eliminates all low producers that will not respond to better feed and care, and feeds the remainder according to known production.



FIG. 11.—The cow testing-association herd that stood highest in butterfat production in 1918, at Grove City, Pa.

The elimination of low producers is important, but it is not the only work of the cow-testing association. The well-managed cow-testing association saves many cows because it furnishes their actual records of production. It discourages the use of the scoop-shovel method of feeding concentrates, by which all the cows are fed alike, and it encourages the feeding of each cow according to known pro-

duction. Through the weighing and testing of the milk it lets the farmer know which are the high testers and persistent milkers. The careful weighing and testing of the milk has caused many an intelligent dairyman to say: "The cow I thought was the poorest turned out to be one of the best in the herd."

The cow-testing association can accomplish much, but there are a few things it can not do. It can not compel a dairyman to dispose of his poor cows if he is determined to keep them. It can not make him feed according to production nor practice economy in the management of his dairy herd. It can not require him to dispose of his scrub bull and buy a better one. It has never yet demanded the planting of legumes and the building of silos. It can never compel, but it will always encourage and point the way to economical improvement of the herd, of the farm, and of the dairy business.

SUMMARY AND CONCLUSIONS.

1. A tabulation of 18,014 yearly individual cow records showed that as butterfat production increased from 100 to 400 pounds there was a regular increase of about \$16 in income over cost of feed per cow for every 50 pounds of increase in average production of butterfat.

2. As production of butterfat increased from 109 to 396 pounds, the returns above the dollar expended for feed increased from 35 cents to \$1.52.

3. Tabulations of the records by herds gave results similar to the tabulations of individual cow records.

4. The records show that cow-testing-association cows are seldom fed beyond the point of economical production.

5. The average milk production of 21,234 cow-testing-association cows, each on test 12 months, was 6,077 pounds, and the average butterfat production was 248 pounds. These figures are about 50 per cent above the estimated averages of all the dairy cows in the United States.

6. Cows having high average production of milk and butterfat averaged high in income above feed cost regardless of breed, age, weight, date of freshening, and geographical location.

7. The cows having an average milk production of 3,250 pounds had an average income of \$32.25 over cost of feed, while the cows having an average milk production of 13,250 pounds had an average income of \$218.19 over cost of feed. The average production per cow in the latter group was about 4 times as great and the average income over cost of feed was nearly 7 times as great as in the other group.

8. This bulletin is based on the tabulation of the figures in 120 sets of records from 96 cow-testing associations.



Washington, D. C.

July, 1922

FARM MANAGEMENT IN CATAWBA COUNTY, NORTH CAROLINA.

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This study is based on a farm business analysis survey of 297 farms, for the year 1912 and of 304 farms for the year 1918 in Catawba County, N. C., and on census reports for that county from 1850 to 1920, inclusive. (Table 1.) The facts brought out, though strictly applicable only to the area surveyed, should offer valuable suggestions to all farmers throughout the lower Piedmont region.

The objects of this study were:

1. To ascertain the type of farming followed and the profits realized in a long-established agricultural community of the southern Piedmont country.

2. To determine the importance of such factors as the size and the quality of the farm business as they affect the economic organization of farms.

3. To bring out the farm practices that enable some farmers to excel others in single enterprises or in the entire farm organization.

4. To note changes that have taken place in the type of farming during the six-year period.

5. To determine the change that has taken place in crop yields, prices received for products, quantities of the several products available for sale, and expenses of operating the farm business, and, so far as practicable, their effect upon the farm profits of the area.

SUMMARY OF RESULTS.

The more important facts brought out by this study may be summarized as follows:

Type of farming.—General crop farming with live stock.

Size of farm.—In 1912 the 297 farms studied averaged 121 acres in size, 57 per cent of the land being tillable. In 1918 the 304 farms studied averaged 111.5 acres in size, 58 per cent of the land being tillable. Most of the untillable land was in woods or in pasture. In 1912 the average value of real estate was \$45 per acre and in 1918 it was \$66.

Capital invested.—The average capital invested in the farms in 1912 was \$6,530, and in 1918 it was \$8,858. About 83 per cent of this represented real estate.

In 1912 a working capital of \$1,070 and in 1918 of \$1,461 was required to operate the average farm.

Income.—For the year 1912 the average labor income was \$86 and for 1918 it was \$542.

For the year 1912 the average family income was \$546 and for 1918 it was \$1,166. This includes money paid on debts, but not the value of food products, fuel, and use of house furnished by the farm, which in 1912 averaged \$328 per farm and in 1918, \$573. In 1912 for all farms of 30 crop acres or under the average amount of the family income was \$260, and in 1918, \$611; for the farms of over 70 crop acres the family income in 1912 averaged \$1,144 and in 1918 \$2,225.

Receipts.—About two-thirds of all receipts were from crops. Cotton, cattle, sweet potatoes, and wheat were the four leading sources of income.

The leading cash crop was cotton, returns from that crop representing about two-fifths of all receipts.

TABLE 1.—*Census data showing changes in the agriculture of Catawba County, N. C., since 1850.*

Item.	1850	1860	1870	1880	1890	1900	1910	1920
Number of farms.....		1,078	698	1,725	2,119	2,647	3,199	2,916
Land in farms, acres...	221,653	221,615	127,954	219,673	237,734	239,824	241,037	217,463
Improved land in farms, acres.....	64,439	67,833	39,203	78,080	101,193	116,379	125,564	113,685
Improved land per farm (acres).....		62.9	56.3	44.4	47.8	44.0	39.2	39
Value of real estate...	\$812,535	\$1,715,639	\$607,424	\$1,723,438	\$2,814,560	\$2,758,590	\$7,324,304	\$10,885,426
Value of machinery...	118,115	85,611	37,387	86,140	124,560	168,680	326,497	734,346
Value of live stock...	221,877	386,207	152,563	241,219	322,710	375,660	763,276	1,250,017
Value of real estate, machinery, and live stock.....	1,152,527	2,187,457	797,374	2,050,797	3,261,830	3,302,930	8,414,077	12,869,789
Milk cows.....	2,581	2,752	1,458	2,871	3,042	3,379	4,891	4,955
Other cattle.....	3,582	3,278	2,135	3,835	4,011	3,979	4,218	3,575
Swine.....	19,891	17,828	6,768	10,594	10,239	8,067	7,187	8,812
Sheep.....	6,280	6,146	4,644	6,299	3,961	1,584	359	184
Butter produced, lbs.	73,337	82,769	29,679	120,784	246,025	379,515	633,739	523,782
Cheese produced, lbs.	1,141	63	100	1,338	425	191	356	280
Milk produced, gals.					1,080,297	1,824,658	1,865,390	1,711,616
Eggs produced, doz.				159,206	187,189	337,680	466,146	467,665
Corn, bushels.....	355,185	403,213	142,876	358,210	317,544	389,280	448,855	401,433
Wheat, bushels.....	52,190	91,702	34,746	104,770	163,977	274,740	135,756	160,182
Oats, bushels.....	65,674	23,799	41,553	64,236	71,875	31,970	87,185	23,478
Rye, bushels.....	5,263	717	1,917	783	1,204	590	7,394	6,980
Cotton, bales.....	652	138	18	2,012	2,412	4,018	6,344	7,311
Hay, tons.....	2,925	1,871	3	1,137	2,504	7,733	7,679	16,417
Sweet potatoes, bush.	21,215	27,661	5,177	19,325	42,447	49,924	195,679	189,938
Irish potatoes, bush.	10,606	9,701	4,540	12,687	22,520	4,531	20,541	17,619
Sorghum sirup, gals.	0	9,747	7,082	28,884	28,340	17,098	21,243	16,178
Tobacco, lbs.....	6,086	9,308	25	26,380	16,400	8,600	633	9,930

GENERAL DESCRIPTION OF AREA.

Catawba County, N. C., is near the center of the western or more elevated half of the Piedmont region of the State. Newton, at the center of the area surveyed, is about 150 miles west of Raleigh and about 75 miles east of Asheville. The surface of the region is rolling, the elevation varying from about 700 feet to about 1,100 feet (fig. 1).

A fringe of rich bottom lands, varying in width from only a few rods to a half mile, borders the important streams. When properly drained these lands produce large yields of corn, small grains, and grasses, and where the elevation is sufficient they make good yields of cotton. Between the bottom lands and the uplands are a series

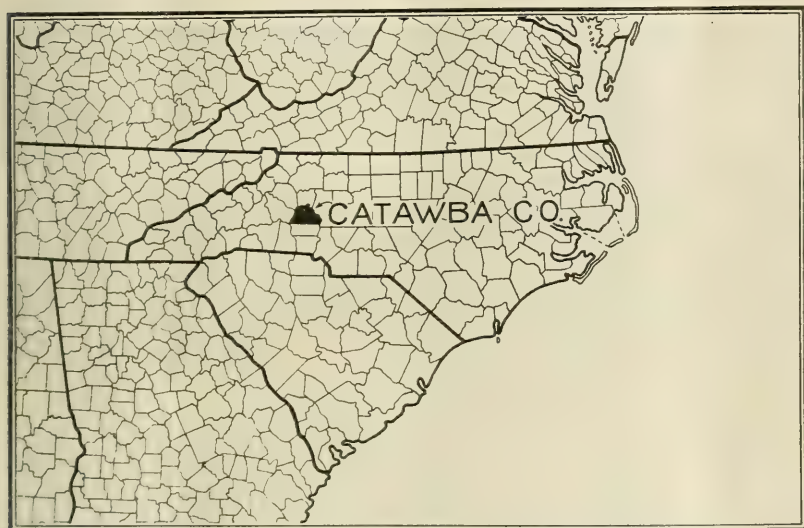


FIG. 1.—Map showing location of area studied.

of slopes. When erosion is prevented by deep plowing and careful terracing, these slopes produce good yields. The steeper slopes in many places have become so eroded that their cultivation is difficult and unprofitable.

The uplands, which constitute by far the greater part of the area surveyed, are more or less rolling, free from steep slopes and bluff formations, and show but few outcropping ledges and boulders. Modern farm machinery can be used to advantage over nearly all these lands. All crops common to the central Piedmont region of the South are grown more or less extensively and successfully. Most of the better class of farm homes are located on these lands (figs. 2, 3, and 4).

The climate, fairly mild and equable, is suitable for the growing of a large variety of farm crops. Extremes of temperature are almost



FIG. 2.—Topography of Catawba County uplands of the better class.



FIG. 3.—Wheat on uplands of the better class.

unknown here. The temperature seldom goes as high as 100° F. or as low as zero.

The elevation, rolling topography, good surface drainage, and abundance of spring and well water, together with the mild and invigorating climate, give this area many advantages as a place of residence.

TYPE OF FARMING AND ANALYSIS OF FARM BUSINESS.

The farmers of this section practice a general or mixed type of crop farming, about two-thirds of all receipts being from crops. In acreage the leading crops are wheat, corn, and cotton. About 38 per cent of the farm receipts in 1918 were from cotton.



FIG. 4.—Farmstead of the better type.

Measured by the receipts derived from various enterprises, the type of agriculture during the very earliest period was live stock, which changed early in the nineteenth century to grain, with live stock as secondary. This continued up to about 1880. At that time cotton became the dominating factor in the type of farming, which position it still holds.

As much grain is grown now as at any time in the history of the county, but cotton has made large gains, while the other enterprises have very little more than remained stationary.

The meat-producing branches of live-stock farming have been losing in importance for more than 70 years. Catawba County is frequently referred to as a dairy county, though very few farmers receive sufficient income from dairy products to warrant their being

classified as dairy farmers. In 1912, 10 per cent of the receipts were from dairy products, and in 1918, 9 per cent.

In Table 2 is given a summary of the farm business of 297 farms for 1912 and 304 farms for 1918. It shows comparisons of the size of farm, crop area, amount of labor, work stock, capital, receipts, expenses, and profits for each sized group for the two years.

TABLE 2.—*Summary of the farm business of 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912					1918				
	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.
Number of farms.....	73	112	62	50	297	75	125	60	44	304
Farm area, acres.....	53.5	90.8	138.5	265.8	121.1	53.0	91.2	129.2	244.8	111.5
Crop area, acres.....	22.6	40.1	60.0	105.0	50.8	22.8	39.1	58.5	101.6	47.9
Months of labor.....	15.9	19.3	22.8	38.2	22.4	15.0	18.7	24.2	36.0	21.4
Number of work stock.....	1.5	2.3	3.3	4.8	2.7	1.7	2.3	3.0	4.5	2.6
Capital.....	\$2,855	\$5,076	\$7,507	\$13,942	\$6,530	\$4,194	\$6,906	\$10,525	\$20,077	\$8,858
Receipts.....	404	702	996	2,067	919	841	1,354	2,056	3,839	1,726
Expenses.....	220	395	543	1,130	506	313	538	869	1,873	741
Farm income.....	184	307	453	937	413	528	816	1,187	1,966	985
Interest on capital at 5 per cent.	143	255	375	697	326	210	345	526	1,004	443
Labor income.....	41	52	78	240	87	318	471	661	962	542
Value of farmer's labor.....	230	269	268	271	260	360	418	448	470	417
Return on capital.....	-2.0%	0.7%	2.4%	4.8%	1.1%	3.9%	6.2%	7.2%	7.0%	6.0%
Farm income.....	\$184	\$307	\$453	\$937	\$413	\$528	\$816	\$1,187	\$1,966	\$985
Value of unpaid family labor..	76	129	148	207	133	83	177	256	259	181
Family income.....	260	436	601	1,144	546	611	993	1,443	2,225	1,166
Family living supplied directly by farm.....	244	313	378	428	328	436	551	677	730	573

The farm income, which is the difference between total receipts and total expenses, averaged \$413 for all farms in 1912 and \$985 for 1918; that is, the farm income was 140 per cent greater in 1918 than in 1912. Farm income is a good indication of the size of business and of the prosperity of the groups of farms studied. It shows the increase that occurred in the earning power of farms as a result of increased prices of farm products. Considering the great drop that has since occurred in prices for agricultural products and the relatively smaller decrease in the prices of supplies the farmer requires, it is probable that the farmer's income for 1920 and 1921 was less than for 1912.

The family income, which is a good measure of the purchasing power of the farmer, was about double in 1918 what it was in 1912. It is likely that 1918 was a year as favorable from the standpoint of income as the farmer may expect in the near future.

The labor income, which represents the amount of money the farmer received for his year's labor after paying all farm expenses, including as expenses the value of labor performed by his family, and

allowing 5 per cent interest on the capital invested averaged \$87 per farm for 1912 and \$542 per farm for 1918.

In addition to this labor income the farmers received house rent and what the farm furnished toward the family living. In 1918 this averaged \$573 per farm. These figures were not obtained direct for 1912, but were calculated by applying 1912 prices to the quantities used in 1918. In 1912 this form of income averaged \$328 per farm.

DISTRIBUTION OF FARM AREA.

The farm area for the 297 farms surveyed in 1912 averaged 121.1 acres per farm, and for the 304 farms surveyed in 1918 it averaged 111.5 acres per farm, or 9.6 acres less per farm (Table 3).

TABLE 3.—*Distribution of farm area on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912					1918				
	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.
Number of farms.....	73	112	62	50	297	75	125	60	44	304
Acres per farm.....	53.5	90.8	138.5	265.8	121.1	53.0	91.2	129.2	244.8	111.5
Tillable area.....	30.2	50.5	81.9	153.5	69.4	30.5	53.1	75.3	136.5	64.0
Crop area.....	22.6	40.1	60.0	105.0	50.8	22.8	39.1	58.5	101.6	47.9
Acres rented out.....	.3			.7	.2	.7	.8	.8	2.5	1.1
Tillable pasture.....	3.2	6.5	11.0	25.0	9.8	3.1	6.9	8.8	21.8	8.5
Idle land.....	4.1	3.9	10.9	22.8	8.6	3.9	6.3	7.2	10.6	6.5
Untillable pasture.....	3.1	6.2	9.9	19.6	8.5	4.4	8.6	12.7	21.7	10.3
Woodland, pastured.....	1.5	3.2	6.5	12.4	5.0	2.9	5.6	9.7	15.4	7.2
Woodland.....	16.0	26.9	37.5	73.1	34.2	15.0	25.9	36.4	75.4	32.4
Waste.....	4.2	7.2	9.2	19.6	9.0	3.1	3.6	4.8	11.2	4.8

The crop area per farm averaged 42 per cent of the total farm area in 1912 and 43 per cent in 1918. In 1912, 12.4 per cent of the acreage of tillable land was lying idle or "resting," while in 1918 this area had been reduced to 10.1 per cent. "Resting land" has long been a practice throughout the South. With low-priced land the practice doubtless has been justified, but as values increase the interest on idle land becomes so great as to make the resting of land to restore its fertility no longer profitable.

Table 4 shows the distribution of capital on the farms in 1912 and in 1918. Both years about four-fifths of the capital on the farms was in real estate. In 1912 the value of real estate was \$45 per acre and in 1918 \$66, or 47 per cent higher. This increase was principally due to the general increase in land values that occurred through this region rather than to improvements on the farm.

TABLE 4.—*Distribution of capital on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912					1918				
	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.
Number of farms.....	73	112	62	50	297	75	125	60	44	304
Average capital.....	\$2,855	\$5,076	\$7,507	\$13,942	\$6,530	\$4,194	\$6,906	\$10,525	\$20,077	\$8,858
Land.....	1,749	3,189	5,096	9,723	4,332	2,477	4,462	6,910	14,579	5,919
Dwellings.....	504	704	788	1,126	743	697	930	1,174	1,301	975
Other buildings.....	158	305	414	851	385	250	390	644	1,062	503
Total real estate.....	2,411	4,198	6,298	11,700	5,460	3,424	5,782	8,728	16,942	7,397
Live stock.....	254	508	706	1,334	626	383	564	940	1,634	748
Machinery.....	93	188	278	436	225	170	248	372	594	303
Feed and supplies.....	77	150	188	407	183	174	258	427	760	344
Cash.....	20	32	37	65	36	43	54	58	147	66
Total working capital...	444	878	1,209	2,242	1,070	770	1,124	1,797	3,135	1,461
Value real estate per acre.....	45	46	45	44	45	65	63	68	69	66

Table 5 shows the sources of receipts on the farms in 1912 and in 1918, and figure 4 shows the distribution of the principal receipts by crop area groups for 1912 and 1918.

TABLE 5.—*Sources of receipts on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912					1918				
	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.
Number of farms.....	73	112	62	50	297	75	125	60	44	304
Receipts, total.....	\$404	\$702	\$996	\$2,067	\$919	\$841	\$1,354	\$2,056	\$3,839	\$1,726
Cotton.....	141	238	342	767	325	285	532	673	1,269	606
Cotton seed.....	3	8	8	47	13	27	46	57	150	59
Sweet potatoes.....	35	64	63	95	62	102	165	249	176	167
Wheat.....	15	44	67	239	75	28	68	145	535	141
Corn.....	21	28	50	98	42	40	82	71	302	101
Other crops.....	47	39	102	125	69	71	96	138	246	120
All crops.....	262	421	632	1,371	586	553	989	1,333	2,678	1,194
Dairy products.....	33	80	85	186	87	87	100	189	348	150
Cattle.....	11	38	45	95	43	20	38	125	386	101
Poultry.....	29	48	59	50	46	56	65	82	119	74
Hogs.....	.....	15	17	75	21	13	44	62	128	52
All other stock and bees.....	3	1	1	15	3	0	1	0	.....	0
Horses and colts.....	6	16	19	35	17	1	3	9	.....	4
All stock.....	82	198	226	456	217	177	251	467	981	381
Woodland products.....	8	19	30	100	32	13	17	59	20	25
Increase feed and supplies.....	8	17	38	85	31	24	38	81	63	47
Miscellaneous.....	43	47	70	55	53	74	59	116	97	79

In 1912 the average receipts per farm were \$919 and in 1918 \$1,726. In 1912, 64 per cent of all the receipts were from crops, 24 per cent

from stock, 3 per cent from woodland products, 3 per cent from increase in inventory of feed, and 6 per cent from miscellaneous sources, consisting principally of labor. In 1918, 69 per cent of the receipts were from crops, 22 per cent from stock, 1 per cent from woodland products, 3 per cent from increase in inventory of feed, and 5 per cent from miscellaneous sources.

In 1912, 37 per cent of the farm receipts were from cotton and cotton seed, while in 1918, 39 per cent of the receipts were from this crop (Table 5).

The amount of cotton sold, however, averaged 2,833 pounds per farm in 1912, while in 1918 it was 2,113 pounds (Table 6).

In 1912, 7 per cent and in 1918, 10 per cent of the receipts were from sweet potatoes. On an average 103 bushels were sold per farm in 1912 and 113 bushels in 1918.

DISTRIBUTION OF CROP AREA.

Table 6 shows the distribution of the crop area, yields, amounts sold, and selling prices of farm products on the farms for 1912 and 1918.

TABLE 6.—*Distribution of crop area, yields, amount sold, and selling prices of farm products on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912					1918				
	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.	30 crop acres or under.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.
Number of farms.....	73	112	62	50	297	75	125	60	44	304
Crop area, total.....	22.6	40.1	60.0	105.0	50.8	22.8	39.1	58.5	101.6	47.9
Wheat.....	5.0	9.4	13.7	25.7	12.0	5.8	10.2	14.9	31.6	13.2
Corn.....	7.5	11.8	15.8	26.8	14.1	7.4	10.5	14.7	25.2	12.7
Cotton.....	4.7	7.1	10.8	20.1	9.4	3.6	6.3	8.2	14.4	7.2
Rye.....	.2	1.1	1.3	2.0	1.1	.3	1.2	1.9	3.1	1.4
Oats.....	1.0	2.7	4.7	8.1	3.6	.6	1.2	2.5	2.2	1.4
Sweet potatoes.....	.8	1.0	1.2	1.6	1.1	.8	1.2	1.7	1.2	1.2
Soy bean and cow pea hay.....	.3	1.0	1.2	3.0	1.2	1.5	2.4	4.5	4.7	2.9
Oat hay.....	.7	1.6	2.4	4.1	1.9	.6	1.1	1.6	1.8	1.2
Red clover hay.....	.2	1.1	1.5	2.8	1.2	.1	1.1	1.5	8.0	1.9
Meadow hay.....	.6	.5	2.6	3.6	1.5	.1	.4	.8	.6	.4
All other crops.....	1.6	2.8	4.8	7.2	3.7	2.0	3.5	6.2	8.8	4.4
Second or intertilled crops.....	1.8	4.2	3.9	8.3	4.2	3.6	4.6	8.8	13.2	6.4
Yield per acre of—										
Wheat.....bu..	10	11	11	13	11	8	8	9	11	9
Corn.....bu..	22	23	23	25	23	23	24	23	26	24
Cotton.....lbs..	270	298	277	328	301	266	293	286	310	293
Rye.....bu..	5	7	7	7	7	5	5	5	6	5
Oats.....bu..	19	19	17	21	20	15	16	17	20	17
Sweet potatoes.....bu..	128	166	139	162	152	139	142	141	151	142
Amount sold—										
Wheat.....bu..	13	40	61	213	67	12	29	60	229	60
Corn.....bu..	24	35	60	118	51	26	54	47	207	67
Cotton.....lbs..	1,261	2,104	2,976	6,575	2,833	965	1,853	2,355	4,479	2,113
Cotton seed.....bu..	12	24	25	142	41	26	45	55	144	57
Sweet potatoes.....bu..	56	106	100	169	103	69	114	102	117	113
Selling price of—										
Cotton.....lbs..	\$0.112	\$0.113	\$0.115	\$0.117	\$0.115	\$0.206	\$0.287	\$0.286	\$0.283	\$0.287
Cotton seed.....bu..	.29	.32	.32	.33	.33	1.03	1.03	1.03	1.04	1.03
Sweet potatoes.....bu..	.62	.61	.63	.56	.60	1.46	1.45	1.54	1.50	1.48
Wheat.....bu..	1.13	1.10	1.10	1.12	1.11	2.35	2.34	2.39	2.33	2.35
Corn.....bu..	.89	.81	.83	.83	.83	1.52	1.53	1.51	1.46	1.50

In 1912, 24 per cent of the crop area was in wheat and in 1918, 28 per cent. This increase in area devoted to wheat in 1918 was largely owing to the demand for wheat that existed at that time and because the Government appealed to the patriotism of the farmers in urging them to grow more wheat. The yield of wheat was low. In 1912 it averaged 11 bushels per acre and in 1918 only 9 bushels. One would expect that where the yields of wheat per acre were low wheat would be less profitable than some other crops yielding a greater money return per acre. Table 7 shows the relation between the acreage of wheat, total receipts, and farm and labor income on 297 farms for 1912 and 304 farms for 1918. It will be seen that, in general, income declines as wheat acreage increases. Where less than 10 per cent of the crop acreage goes into wheat a poor yield will not cut down the farm income very much, but where much over 10 per cent of the crop acreage is in wheat it is important to make an effort to increase the yield.

TABLE 7.—*Relation between per cent of total crop land in wheat and total receipts, farm income, and labor income on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912.						1918.					
	10 per cent and less.	10.1 to 20 per cent.	20.1 to 30 per cent.	30.1 to 40 per cent.	Over 40 per cent.	All farms.	10 per cent and less.	10.1 to 20 per cent.	20.1 to 30 per cent.	30.1 to 40 per cent.	Over 40 per cent.	All farms.
Number of farms....	30	82	117	51	17	297	12	75	119	68	30	304
Crop area, acres....	45.2	51.5	48.8	55.4	52.4	50.8	30.1	45.6	46.6	49.0	63.7	47.9
Acres in wheat.....	1.7	8.4	12.1	19.1	24.4	12.0	1.2	7.5	11.6	16.8	30.0	13.2
Total receipts.....	\$1,446	\$967	\$858	\$917	\$885	\$919	\$1,302	\$1,854	\$1,766	\$1,658	\$1,873	\$1,726
Receipts from wheat.	7	42	64	142	219	75	4	50	103	184	468	141
Farm income.....	583	440	356	407	402	413	784	1,059	1,033	859	969	985
Labor income.....	196	134	61	44	-29	86	482	635	601	431	346	542

To show the effect of increased yields of wheat on income, all farms that had over 30 per cent of their crop acreage in wheat were grouped into two groups; the first group consisted of all farms on which the yield of wheat was below the average, the second group of those with yield above the average. In 1912 the average acreage of wheat per farm for these groups was 20.4 acres. There were 39 of these farms with an average yield of 8.6 bushels per acre. Their farm income was \$260 and labor income was a minus \$69. There were 29 farms with an average yield of 14.6 bushels per acre which had an average farm income of \$601 and an average labor income of \$153.

In 1918 the average acreage of wheat per farm for these groups was 20.8 acres. The 62 farmers having over 30 per cent of their crop acreage in wheat, but with yields averaging 6.5 bushels per acre,

had average farm incomes of \$710 and labor incomes of \$301, while the 36 farmers who had a yield of wheat averaging 11.9 bushels per acre had an average farm income of \$1,207 and an average labor income of \$585.

In spite of the fact that the low yield, the topography, and the type of farming followed make the cost of raising wheat high and its production therefore relatively less profitable than that of some other crops, farmers grow wheat here because they do not like to buy flour for bread and do not think it is a mark of good farming to do so. Moreover, the presence of local flour mills makes it easy to have their wheat ground. A small acreage of wheat does not materially interfere with other crops. It fits well into the rotation and is a good nurse crop for clover. Wheat sells at a higher price here than in the wheat belt, and a little wheat to sell in the summer brings in ready cash when it is needed most. The wheat crop is thus the medium through which important steps in raising the cotton crop are financed.

The corn crop occupied 28 per cent of the crop area in 1912 and 26 per cent of the area in 1918. The average yield per acre was 23 bushels in 1912 and 24 bushels in 1918. In both years in which the study was made there was only one farm that did not grow corn. The acreage of corn which the farmer should grow is a question that arises annually. Table 8, showing the relation between the acreage of corn and the farm and labor income on 297 farms for 1912 and 304 farms for 1918, may help to solve the question.

TABLE 8.—*Relation between per cent of total crop land in corn, and total receipts, farm income, and labor income on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	Per cent of crop area in corn.											
	1912.						1918.					
	10 per cent and less.	10.1 to 20 per cent.	20.1 to 30 per cent.	30.1 to 40 per cent.	Over 40 per cent.	All farms.	10 per cent and less.	10.1 to 20 per cent.	20.1 to 30 per cent.	30.1 to 40 per cent.	Over 40 per cent.	All farms.
Number of farms....	5	56	111	86	39	297	5	61	123	84	31	304
Crop area.....	40.1	61.3	53.7	47.1	37.4	50.8	33.0	59.9	49.2	42.4	36.8	47.9
Acres in corn.....	4.6	9.8	13.3	16.2	18.0	14.1	2.8	9.3	12.3	14.5	17.4	12.7
Total receipts.....	\$687	\$1,333	\$937	\$860	\$740	\$919	\$1,441	\$2,332	\$1,733	\$1,615	\$1,146	\$1,726
Receipts from corn.....	16	13	40	52	72	42	4	58	80	134	195	101
Farm income.....	306	573	394	379	328	413	906	1,292	972	902	665	985
Labor income.....	62	134	56	123	278	87	375	726	545	492	326	542

Disregarding the first groups of farms, both in 1912 and in 1918, since there are only five farms in each, too small a number to make the conclusions very reliable, it will be seen that for both years the farmers making the highest farm incomes were those growing the smallest acreages of corn.

To show the effect of increased yields of corn per acre on farm profits, only farmers with over 30 per cent of their crop acreage in corn were selected. Of course other factors besides the yield of corn influenced the profits on these farms, but where so great a proportion of the crop acreage was in corn the yield of that crop was bound to have considerable weight.

In 1912 farmers who got a yield of only 16 bushels of corn per acre made an average labor income of \$48, while those with a yield of 30 bushels per acre got an average labor income of \$175. It will be remembered that the average labor income of all farms in 1912 was \$87. In 1918 the farmers who got less than an average yield



FIG. 5.—Catawba County cotton field. Cotton is the main money crop of this area.

of corn got an average labor income of \$337, while those with an average yield of 31 bushels of corn per acre got an average labor income of \$633. In 1918 the average labor income of all farms was \$542.

Among factors favorable to the growing of corn may be cited the fact that it is an excellent feed for farm stock; that any surplus has a ready market at good prices in this region; and that on lowlands very large yields per acre are possible. Among the unfavorable factors are the fact that it competes with cotton and sweet potatoes for labor; that the yield is generally low, in 1912 averaging 23 bushels per acre, and in 1918 24 bushels; and that weevils often causes considerable damage.

The cotton crop occupied 19 per cent of the crop area in 1912 and 15 per cent of the area in 1918. The average yield per acre was 0.6 bale (301 pounds) in 1912 and 0.59 bale (293 pounds) in 1918. In 1912 and 1918, 18 farmers raised no cotton. With the exception of sweet potatoes, cotton returns higher receipts per acre than any other crop that is extensively grown in this area. As has been pointed out in the preceding pages, from the standpoint of receipts, cotton is the leading enterprise. Table 1 (page 2) shows the increasing importance of the cotton crop in this county since 1850 (see fig. 5).

In 1912, with cotton selling at 11.5 cents per pound, the study indicated that from 20 to 40 per cent of the crop land planted to cotton gave the highest farm and labor income. That year 37 per cent of all the farms came in that group. In 1918, with cotton selling at 28.7 cents per pound, the farmers who had 10 to 30 per cent of their crop land in cotton got the highest incomes. That year 63 per cent of all the farms came in that group.

Table 9 shows very strikingly the effect of high yields on income. For example, in 1912 the farms had an average of 22.1 acres of cotton per farm, but with a yield below the average made an average labor income of \$74, while the small farms that had an average of 9.1 acres per farm, but with a yield above the average, made an average labor income of \$189 per farm. The farmers who had the largest acreage in cotton and the highest yields per acre made an average labor income of \$683.

TABLE 9.—Effect of increased yields of cotton per acre on farm income and labor income on 129 farms for 1912 and 84 farms for 1918 with over 20 per cent of their crop acreage in cotton, Catawba County, N. C.

Item.	1912				1918			
	Yield of 301 pounds or less per acre.		Yield of over 301 pounds per acre.		Yield of 293 pounds or less per acre.		Yield of over 293 pounds per acre.	
	50.8 crop acres or less.	Over 50.8 crop acres.	50.8 crop acres or less.	Over 50.8 crop acres.	47.9 crop acres or less.	Over 47.9 crop acres.	47.9 crop acres or less.	Over 47.9 crop acres.
Number of farms....	52	26	28	14	39	11	22	12
Average acres in cotton.....	9.7	22.1	9.1	27.9	9.1	20.2	7.9	19.4
Average yield per acre.....pounds..	238	242	369	396	232	225	374	361
Farm income.....	\$214	\$451	\$388	\$1,423	\$727	\$1,266	\$1,106	\$2,076
Labor income.....	28	74	189	683	466	647	744	1,488

In 1918 the farms that had an average of 20.2 acres of cotton per farm, but with a yield below the average, made an average labor income of \$647, while the small farms that had only 7.9 acres of cotton per farm, but with a yield above the average, made a labor income of \$744. The 12 farmers averaging 19.4 acres of cotton per

farm, but with a yield above the average, made an average labor income of \$1,488, which is over twice as large as the average of the group of farms with 20.2 acres of cotton per farm but with a yield below the average. Table 9 shows that the maximum profits, both in 1912 and in 1918, were made by the farmer who had an acreage of cotton above the average and yielding above the average.

The sweet potato crop occupied 2 per cent of the crop area in 1912 and 2.5 per cent of the crop area in 1918. As shown in Table 5, 7 per cent of the receipts were from sweet potatoes in 1912 and 10 per cent in 1918. The amount sold per farm averaged 103 bushels in 1912 and 113 bushels in 1918. In 1912 the average price received per bushel was 60 cents and in 1918 it was \$1.48.

More farmers raised sweet potatoes in 1918 than in 1912. In 1912 31 per cent of the farmers did not raise sweet potatoes, while only 22 per cent did not raise them in 1918. The number of farmers depending upon sweet potatoes as a source of cash receipts is increasing. In 1912 169 farmers, or 57 per cent of the total, reported sales of sweet potatoes, and in 1918 195 farmers out of 304, or 64 per cent, reported receipts from sweet potatoes.

TABLE 10.—*Relation between yield per acre of sweet potatoes and farm income and labor income on farms having over 5 per cent of their crop acreage in sweet potatoes—47 farms for 1912 and 59 farms for 1918, Catawba County, N. C.*

Item.	1912		1918	
	152 bush- els or less per acre.	Over 152 bushels per acre.	142 bush- els or less per acre.	Over 142 bushels per acre.
Number of farms.....	31	16	25	34
Average acreage in sweet potatoes.....	3.6	3.4	3.4	3.2
Average yield.....bushels..	113	204	108	177
Farm income.....	\$327	\$488	\$829	\$1,166
Labor income.....	48	162	467	801

In 1912 the farmers who secured an average yield of 113 bushels per acre made an average labor income of \$48, while those who averaged 204 bushels per acre made a labor income of \$162 (Table 10).

In 1918 farmers who secured an average yield of 108 bushels per acre made labor incomes of \$467, while those who averaged 177 bushels per acre made an average labor income of \$801 per farm. Of course, not all this difference in income can be directly attributed to difference in yield of sweet potatoes, but certainly some of it can.

Some important factors that are favorable for raising sweet potatoes in this region are a climate and soil well adapted to the crop so that good yields are the rule, successful cooperative marketing associations, and a community of farmers who are experienced in raising the crop. The unfavorable factors are those common to nearly all sweet potato growing areas, namely, plant diseases, diffi-

culty in keeping the crop, and distance from producer to consumer. Then there is the objection that to a certain extent it competes for labor with another high money value crop—cotton.¹

From the standpoint of acreage in 1912 and again in 1918, hay was the crop fourth in importance. Very little hay is sold, but most farmers grow all the hay needed for their live stock. In 1912 the value of hay bought per farm was \$3 and in 1918 it was \$5.

Hay fits in fairly well in the rotation, does not compete very seriously for labor with other crops, is useful as a catch crop, and, if a legume, improves the soil.

The climate and soil are favorable for raising a wide variety of truck crops, but the local demand for these products is very limited and competition with other regions is keen, hence comparatively little truck is grown.

Some fruit is grown on every farm for home use, but very little is sold.

Table 11 shows the distribution of live stock and selling prices of some stock products on the farms studied in 1912 and 1918. There was a slight decrease in the number of productive animal units² per farm from 1912 to 1918. In 1912 there were six productive animal units per farm, and 5.6 in 1918. Table 5 showed that in 1912 24 per cent and in 1918 22 per cent of all the farm receipts were from live stock.

TABLE 11.—*Distribution of live stock and selling prices of some products on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912					1918				
	30 crop acres or less.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.	30 crop acres or less.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.
Productive animal units.	2.8	5.3	6.9	10.9	6	3.0	4.4	6.7	11.8	5.6
Number of cows.	1.6	2.6	3.5	4.7	2.9	1.8	2.4	3.5	6.1	3.0
Number of brood sows.	1.3	.6	.9	1.2	.7	.3	.6	1.0	1.4	.7
Number of chickens.	37	49	65	69	53	39	42	53	65	47
Number of work stock.	1.5	2.3	3.3	4.8	2.7	1.7	2.3	3.0	4.5	2.6
Selling prices:										
Butter, pound.	\$0.20	\$0.20	\$0.22	\$0.26	\$0.22	\$0.28	\$0.39	\$0.37	\$0.37	\$0.36
Hogs, pound dressed.					.0925					.22
Eggs, dozen.	.18	.18	.18	.18	.18	.35	.35	.35	.35	.35

Dairy cattle were the principal productive animals kept on these farms. In 1912 cows averaged 2.9 per farm, and 3 in 1918. Jerseys,

¹ Where the control method, worked out by the U. S. Department of Agriculture are used the effect of disease on the sweet potato crop may be discounted. Moreover, the difficulties formerly encountered in keeping this crop are rapidly being overcome by the development of proper storage method.

For details as to growing sweet potatoes, see Farmers' Bulletin 999, "Sweet-Potato Growing."

² A productive animal unit is a grown steer, cow, or horse or its equivalent in small animals—5 hogs, 7 sheep, or 100 fowls.

grade or purebred, or crosses containing Jersey blood, were the most numerous. In 1912 the average dairy cow was valued at \$47.81, and in 1918 at \$79.05.

In 1912 and in 1918 about 9 per cent of all the farm receipts were derived from the sale of dairy products. It is considered locally that Catawba County is a fairly well developed dairy section, but many of the farmers keep only one or two cows, principally for home use, selling a small amount of butter or cream during the season of highest production. In 1912, eighty-eight per cent and in 1918, eighty-three per cent of the farmers sold some dairy products.

Recently considerable interest has been taken in the further development of the dairy enterprise throughout much of the Piedmont country. At the time the survey was made there was one creamery in the area and several more were within a few miles of the surveyed area. Cream routes have been established over the greater part of the territory.

Several bull associations have recently been organized, and a number of high-class purebred dairy bulls have been brought into the area by others. Most of the dairy cows here are of poor quality, however, and altogether too many farmers fail to give enough attention to using good sires and to weeding out the poor cows from their herds.

In 1912, 5 per cent, and in 1918, 4 per cent of all the farm receipts came from poultry. In 1912, the average number of chickens per farm was 53; in 1918 the number had decreased to 47. All of the farmers kept some poultry, but in spite of the efforts that have been made to encourage the keeping of poultry in the area, there were no large flocks on any of the farms.

In 1912 the receipts from hogs averaged \$21 per farm; in 1918, \$52 per farm (Table 5). The average number of brood sows per farm each year was 0.7; that is, on every 10 farms studied there were 7 brood sows. The number of swine on farms in Catawba and nearby counties of the Piedmont region has decreased continuously since 1880. The wisdom of this change in practice has frequently been questioned; nevertheless it continues and apparently is becoming more marked decade by decade. Only about one-half of the farmers sold hogs or pork. It is questionable whether under existing conditions much extension of hog raising could be recommended. On many farms, however, more hogs could be kept to consume feed that otherwise would be wasted.

Table 12 shows the distribution of expenses on the farms for 1912 and for 1918.

TABLE 12.—*Distribution of expenses on 297 farms for 1912 and 304 farms for 1918, Catawba County, N. C.*

Item.	1912					1918				
	30 crop acres or less.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.	30 crop acres or less.	30.1 to 50 crop acres.	50.1 to 70 crop acres.	Over 70 crop acres.	All farms.
Total expense per farm.....	\$220	\$395	\$543	\$1,130	\$506	\$313	\$538	\$869	\$1,873	\$741
Expense for—										
Cropper labor.....	7	8	29	95	27	16	48	100	530	120
Hired labor and board.....	13	40	81	298	85	8	20	76	273	64
Unpaid family labor.....	76	129	148	207	133	83	177	256	259	181
Repairs—										
Machinery.....	5	9	10	20	10	7	12	20	37	16
House.....	6	8	11	15	10	8	11	16	18	12
Other buildings.....	3	6	7	17	7	5	7	10	16	8
Fences.....	2	5	6	10	5	1	2	3	5	3
Feed bought—										
Hay, etc.....	3	1	2	5	3	3	3	9	6	5
Grain, etc.....	13	30	30	79	34	29	26	55	135	48
Fertilizer.....	29	47	71	130	61	44	70	99	218	91
Ginning.....	6	10	13	29	13	9	19	24	41	21
Other machine work.....	1	3	3	5	3	4	5	7	18	6
Insurance.....	1	2	3	3	2	1	2	2	3	2
Taxes.....	11	18	25	49	23	17	26	34	58	30
Other items.....	10	21	29	46	24	26	40	61	110	52
Total current expense...	186	337	468	1,008	440	261	468	772	1,727	659
Depreciation:										
Machinery.....	12	24	35	59	29	18	28	37	65	33
House.....	14	19	21	26	20	20	23	27	26	24
Other buildings.....	8	13	18	37	17	11	18	29	44	22
Total.....	34	56	74	122	66	49	69	93	135	79

In 1912 the total expense per farm averaged \$506; in 1918, \$741, an increase of 46 per cent. The largest single item of cash expense in 1912 was that of hired labor, amounting to \$112 per farm. In 1918 this item amounted to \$184 per farm. The value of unpaid family labor was estimated by the farmer in 1912 at \$133 and in 1918 at \$181. The next largest item of expense was for fertilizer. In 1912 this bill amounted to \$61 per farm; in 1918, \$91. The cost of repairs on machinery, buildings, and fences averaged \$32 per farm in 1912 and \$39 per farm in 1918. Depreciation on machinery and buildings, though not a cash expense, nevertheless represents a charge that ultimately must be met, and this averaged \$66 per farm in 1912 and \$79 per farm in 1918.

CROP ROTATIONS.

The pioneer farmer of this area, and his successors for two or three generations, had no systematically planned crop rotation. Soil fertility problems were not recognized, and for other reasons rotation of crops was not desired. Even at present, crop rotation is not generally practiced on these farms. Practically all rotations yet suggested for the region have serious defects of adaptation to commercial agriculture.

Certain natural conditions have directed the agriculture on some of these lands into a long rotation. The red lands and also the gray, when first brought under cultivation, produced good crops of corn and small grain. In a few years the corn yield dropped off, so that the crop was no longer profitable. Wheat held up to or above the line of profitable yield for some time longer. It then went below this line, but the losses were not very heavy for some time, and wheat continued to be sown, even though not a profitable crop. After a few years more, however, the losses became so great on exhausted lands that wheat was no longer sown. These lands never have been well suited to grazing, and rather than risk time and effort in con-



FIG. 6.—Early stage of "resting" land. Broom sedge and briars in foreground, old field pine in distance.

verting them into hay or pasture they were turned out to grow up, first to broom sedge, then bushes, and finally to "old field," or second-growth pines (fig. 6). While a few acres of the poorer land on the farm may thus be abandoned each year, an approximately equal area of new land is cleared up and used, first for corn, then for small grain, till in the course of time it also is turned out to grow up. Thus on many of the lands of only moderate natural fertility, a long rotation has been established, perhaps unconsciously.

The time required to complete one cycle in the rotation established by the farmer and nature working together is variable. It may be 20 years or it may be 50. Usually, though, it is a little more than the lifetime of a generation of farmers. The grandson clears up and farms these old fields abandoned late in the lifetime of the grandsire.

The visible but unrecorded cropping history of the region is full of examples of these long rotations. How successfully they have fulfilled their mission is shown by the fact that these old fields, when re-cleared and planted, yield almost if not fully as well as when put under cultivation the first time.

On the better grade of lands conditions have been such as to foster a shorter rotation. The strong lands first cleared of the original forest growth continued to give profitable crops for a considerable period, perhaps a dozen years or more. From 2 to 5 years of rest then suffices to bring them back into a profitable state of fertility. The second cropping period was generally of shorter duration than the first while the time for recuperation was fully as long. Thus in the course of time lands come to be cultivated from 3 to 5 years and then lay out (rested) from 1 to 2 years, while occasionally they were cropped 2 years and rested 1.

The shorter rotation consisted very generally of nonleguminous plants to be disposed of commercially, and broom sedge, weeds, and brush during the soil-resting period. The completion of a cycle in the rotation required from 3 to 7 years, according to the degree of exhaustion of the soil.

Neither of these natural rotations has entirely gone out of use. "Land resting" is still practiced on a considerable percentage of the farms, but the practice is not so universal as it was a few decades ago. In 1912 12.4 per cent and in 1918 10.1 per cent of the tillable land in farms was classified as idle or resting.

The turning out of land to grow up in second-growth or old-field pines is becoming less common with each succeeding generation, and bids fair to cease entirely, in the course of a few decades, or to be confined to lands which really should never have been put under cultivation.

SUGGESTED CROP ROTATIONS.

According to the findings of this survey, rotations used in the Piedmont regions should give prominence to the cotton crop, unquestionably the most important and profitable farm enterprise for the area. The rotations should be such as to utilize to a very full extent the entire crop land of the farms. In general practice the rotation calling for some double cropping should be preferred over others. The rotation should be so planned as to prevent the necessity of resting land, and with a view to utilizing labor, teams, and equipment to the fullest possible degree. Due regard must be given to increasing soil fertility. To this end summer legumes and winter cover crops, both leguminous and nonleguminous, should be grown. In order to utilize teams and labor to the best advantage, considerable land should be available for the late fall, winter, and early

spring plowing. This is important. Attention should be given to the crops necessary for feeding live stock and also for furnishing home supplies. The difficulty of adapting different crops and enterprises to different soil types is a factor in determining rotations. On the farm with only one or two types of soil, all of it upland and suitable to a considerable variety of crops, a rotation is easy to plan. When the farm has only lowlands, certain crops must be eliminated and the importance of others magnified in the rotation. On farms with both upland and lowland, one rotation may be required for one part and an entirely different one for the other.

With these points in mind the rotations here suggested have been arranged. As they are studied the importance given to certain enterprises becomes apparent. The fact that one or two rather important enterprises (sweet potatoes, for instance) are not mentioned will be noted. On a great majority of places such crops will be grown only on limited acreages. Their period of growth and cultural requirements are such that they may readily be substituted for some other crops. For example, cotton will be planted in April or May. Sweet potato land should be prepared at the same time or shortly thereafter. The plants should be set in the fields in May or June. If importance in the farming system is to be given to sweet potatoes, a few acres of the land intended for cotton in the rotation can be set aside for the potatoes.

In considering the individual rotations it should be borne in mind that the findings of the survey are that those farms having a comparatively large percentage of their crop land in cotton have better incomes than those upon which this crop occupies but a small percentage of the land, and that when corn yields are above 30 bushels to the acre the farms having over 20 per cent of their crop land planted to this crop have better incomes than the others. The farms having from 10 to 15 per cent of their land in wheat and from 5 to 10 per cent in oats, especially when the yields are somewhat above the average, have a maximum labor income. The farms getting a hay harvest from 20 to 30 per cent or even more of their lands are among the more prosperous. A moderate acreage of sweet potatoes seems to increase farm profits.

The first rotation suggested covers 5 years, gives 40 per cent of the land to cotton, 20 per cent to corn, 20 per cent to small grain (wheat and oats combined), and from 30 to 40 per cent to hay crops, counting double cropping. It keeps practically 60 per cent of the land covered during the winter and makes 40 per cent available for fall and winter plowing. (Rotation 1.)

ROTATION 1.—*Five-year crop rotation for Catawba County, N. C., and other southern Piedmont areas.*

First year. COTTON. After first year's cotton is picked the land may be plowed in winter for second-year cotton crop.

Second year.—COTTON. Planted to rye or crimson-clover cover crop, to be plowed under in spring for third-year corn crop.

Third year.—CORN. Peas or soy beans planted in corn: seed picked, vines disked in, small grain sown in October or November; seeded to red clover in February or March.

Fourth year. SMALL GRAIN. If clover catches, make one cutting of clover hay; otherwise pea or soy bean hay, and then seed to crimson clover.

Fifth year. HAY. One cutting of red-clover hay, or save crimson-clover seed, disk or plow stubble, and plant peas and soy beans for hay. In fall and winter plow for sixth-year cotton.

The five-year rotation may be shortened one year by omitting one hay crop, in which case the farm should be arranged in four fields, two of these planted to cotton, one to corn, and one to small grains, the corn, of course, being followed by cowpeas or soy beans, and the small grain by the same legumes sown broadcast and harvested for hay. This gives 50 per cent of the land to cotton, 25 to corn, 25 to small grain, with a summer crop of hay of 25 per cent. A second method of shortening the five into a four-year rotation is to drop one year of cotton; this brings the cotton acreage down to 25 per cent, leaves 25 per cent in corn, 25 per cent in small grain with clover as a possible fall hay crop, and 25 per cent in clover hay for the June cutting. This rotation will not produce as large a gross income as will the five-year rotation with 40 per cent cotton or the four-year with 50 per cent cotton. However, the expense will not be quite so great and the ultimate net result may possibly be a little greater. It is not difficult to make either of the transitions suggested. (Rotation 2.)

ROTATION 2.—*Four-year crop rotation for Catawba County, N. C., and other southern Piedmont areas.*

First year. COTTON. Planted in April or May; picked from September to December; land available to plow from late fall to middle of spring.

Second year. COTTON. Planted in April or May; first picking in September; plant cover crop; land available for spring plowing.

Third year. CORN. Planted in April or May; at last working, plant cowpeas in middles for seed and humus crop; small grain planted in fall.

Fourth year. SMALL GRAIN. Harvested in June; cowpeas or other summer legumes for hay or seed; land available to plow from late fall to spring.

The three-year rotation has been recommended throughout the Piedmont region more extensively than any other and is perhaps the basis of rotations wherever we find them now followed. (Rotation 3.)

ROTATION 3.—*Three-year crop rotation, Catawba County, N. C., and other southern Piedmont areas.*

First year. COTTON. Planted in April and May; first picking in September; cover crop crimson clover or rye planted; land available to plow in spring.

Second year. CORN. Planted in April or May; peas planted in middles at last working of corn; seed picked; land disked and small grain planted.

Third year. SMALL GRAIN. Peas or soy beans planted for hay or seed; land available for fall and winter and early spring plowing.

This arrangement allows approximately one-third for cotton, one-third for small grain, and one-third for corn. If more than the usual amount of stock is being kept this may perhaps be a more desirable rotation than those already described.

For some special cases a two-year rotation, with 50 per cent of the land in cotton, may be desirable. This rotation in addition to giving 50 per cent of the land to cotton gives 25 per cent to small grain, 25 per cent to summer hay crops, and 25 per cent to corn with summer legumes between the corn rows, and with the aid of the manure made on the place will keep the humus content of the soil up to a fairly good standard. This rotation is not recommended for land of a low degree of fertility, nor for farms requiring a great deal of corn and hay for live stock.

ROTATION 4.—*Two-year upland crop rotation for Catawba County, N. C., and other southern Piedmont areas.*

First year. COTTON. Planted in April and May; first picking in September; one-half field planted in small grain; one-half plowed in winter and spring for corn.

Second year. SMALL GRAIN AND CORN. From half of field small grain harvested in June; cowpeas or soy beans for hay or seed; other half of field corn planted in April or May; peas planted in middles at last working; hay harvested in September; corn and peas gathered in October and November; land available for winter and spring plowing.

Occasionally different rotations are wanted for different classes of land on the farm. The farm having both uplands and bottom lands should have a rotation in which cotton is by far the most important crop for the higher lands and one in which preeminence is given to corn for the bottom lands.

For the upland fields, or cotton land, the suggested rotation covers a period of 3 years. (Rotation 5.)

ROTATION 5.—*Three-year upland crop rotation for Catawba County, N. C., and other southern Piedmont areas.*

First year. COTTON. Planted in April and May; first picking in September; cover crop crimson clover or rye; land available for spring plowing.

Second year. COTTON. Planted in April and May; first picking in September; small grain planted after second picking—October.

Third year. SMALL GRAIN. Harvested in June; cowpeas or soy beans for hay, or seed; land available for fall, winter, and spring plowing.

On other lands corn should receive a prominent place. For this purpose a two-year rotation is suggested. (Rotation 6.) When the land is somewhat evenly divided between the upland and lowland the three-year cotton rotation and the two-year corn rotation together make a very desirable system. Of course these rotations may be varied to suit different conditions.

ROTATION 6.—*Two-year lowland rotation for Catawba County, N. C., and other southern Piedmont areas.*

First year. CORN. Plow in April or later and plant corn from April to June; harvest in September or October; disk land and drill oats or other winter and spring crops.

Second year. OATS. Harvest in May or June; plow or disk and plant cowpeas or soy beans for hay and seed; cover crop from September to April.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1071



Washington, D. C.

July 12, 1922

INFLUENCE OF SEASON OF FRESHENING ON PRODUCTION AND INCOME FROM DAIRY COWS.

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BASIS OF THE DATA.

There is a widespread belief that cows produce more milk and butterfat, and that they produce more economically, if they freshen in the fall or winter than if they freshen in the spring or summer. Tabulations of cow-testing-association records show that a definite relation does exist between season of freshening and other factors, but that the relation is not the same everywhere and under all conditions. That relation seems to depend to some extent on cost of feed, condition of pastures, and geographical location with reference to markets.

Under such circumstances a study of averages for a large number of cow-testing associations taken indiscriminately might be misleading unless followed by a further study of the records of each association. The conclusions given in the following pages are based on averages of the records of 64 associations combined, and on averages of the records of each association. The figures cover the period 1910 to 1920, inclusive. From each association the records used were for one year only. To avoid possible error due to incomplete data or to short-time tests, records were discarded if the breed and age were omitted or if the cow was on test less than 12 months. Tabulations on breed and age showed that these were not factors influencing the conclusions drawn in this bulletin. In the 64 associations studied there were on yearly test 10,870 cows whose age and date of freshen-

ing were given. The computations in this bulletin are based on the records of these cows. Cost of feed and price of product are based on actual figures as given by the testers on the individual cow record sheets.

INFLUENCE OF SEASON OF FRESHENING.

In Table 1 the records of the cows on test 12 months in 64 cow-testing associations are grouped according to the season when the cows freshened.

TABLE 1.—*Date of freshening, by seasons, with average yearly feed and production records, per cow.*

Season.	Number of cows.	Milk production.	Butter-fat production.	Cost of roughage.	Cost of grain.	Cost of feed.	Income over cost of feed.
Spring (March, April, and May).	3,196	<i>Pounds.</i> 5,842	<i>Pounds.</i> 236	\$37.51	\$19.22	\$56.73	\$70.73
Summer (June, July, and August).....	1,328	5,941	236	37.62	22.48	60.10	66.59
Fall (September, October, and November).....	2,862	6,689	268	38.94	28.45	67.39	76.65
Winter (December, January, and February).....	3,484	6,439	258	37.65	25.51	63.16	75.66
Total and averages.....	10,870	6,269	252	37.95	24.06	62.01	73.36

The cows that freshened in the fall months ranked highest in average yearly production of milk and butterfat, in cost of feed and in income over cost of feed. In all these points, the cows that freshened in the winter ranked second. Of the 10,870 cows, 6,346 freshened in the fall and winter and 4,524 freshened in the spring and summer. On an average the cows that freshened in the spring produced the least milk and those that freshened in the summer produced the least income over cost of feed. Care and quality of cows are big factors in determining production and income, but the large number of records in each group would tend to prevent great variation among group averages due to such causes.

Fewer cows freshened in the summer than at any other season. This may have been due partly to a belief among dairymen that it pays better to have cows freshen at some other time of year, a belief that seems to be supported generally by the records. It is also true that the season of freshening can not always be controlled. The feed bill, especially the amount spent on grain, was lowest for the cows that freshened in the spring. This was doubtless because the long pasture period, when little grain was fed, came during the early part of the lactation period. The total cost of feed, however, was not low enough to give the cows that freshened in the spring first or even second place in yearly income over cost of feed. If cost of labor were to be included, the figures would doubtless be even more favorable to fall and early winter freshening, on account of the scarcity and high cost of labor in some districts during the summer months.

VALUE OF PRODUCTS.

Table 2, which is derived from a tabulation of the records of the 64 associations, shows how many times the cows that freshened each season ranked first, second, third, and fourth in average yearly price received for milk or butterfat produced by the cows that freshened within that season.

TABLE 2.—Seasons when cows freshened ranked according to average price of butterfat or milk.

Season of freshening.	Number of times ranked.			
	First.	Second.	Third.	Fourth.
Spring.....	12	11	14	27
Summer.....	36	14	9	3
Fall.....	39	18	5	2
Winter.....	12	20	26	6

The figures do not refer to the price received for the product at any season of the year, but to the average price received during the entire year for the product produced by cows that freshened at a certain season.

There were two associations in which no cows freshened in summer. This accounts for the summer ranks adding up to only 62.

As there were ties for first place in some associations, the total number of times the four seasons received first place is greater than the number of associations compared. The table shows that in average price received for butterfat produced during the year, fall freshening ranked first 39 times; summer, 36; winter, 12; and spring, 12. The cows that freshened in the fall may not have freshened at the time of year when prices were highest, but they produced most of their milk at the time of year when prices were highest.

MILK AND BUTTERFAT PRODUCTION.

In milk production the ranks of the four seasons were as shown in Table 3:

TABLE 3.—Seasons when cows freshened ranked according to average yield of milk.

Season of freshening.	Number of times ranked.			
	First.	Second.	Third.	Fourth.
Spring.....	7	13	24	20
Summer.....	10	4	19	29
Fall.....	29	23	7	5
Winter.....	18	24	14	8

In average yearly milk production, fall ranked first in 29 associations and second in 23 associations. Winter ranked first in 18 associations and second in 24. Summer ranked first in 10 associations and

spring ranked first in only 7. It is also worthy of note that in milk production spring and summer ranked third and fourth in most of the cases.

Table 4 shows the number of times each season ranked first, second, third, and fourth in butterfat production:

TABLE 4.—Seasons when cows freshened ranked according to average production of butterfat.

Season of freshening.	Number of times ranked.			
	First.	Second.	Third.	Fourth.
Spring.....	7	8	27	22
Summer.....	8	6	17	31
Fall.....	38	16	7	3
Winter.....	13	35	11	5

Out of a possible 64, fall ranked first 38 times in average yearly production of butterfat per cow and second 16 times. Winter ranked first 13 times and second 35 times out of a possible 64. Summer ranked first 8 times and fourth 31 times out of a possible 62, there being two associations in which no cows freshened during the summer months. Spring ranked first only 7 times in butterfat production and second 8 times. In average pounds of butterfat produced per cow for all associations combined (see Table 1) fall ranked first, winter second, and spring and summer tied for third and fourth places.

Figure 1 shows graphically the variation of butterfat production according to season of freshening for the 10,870 cows in the 64 associations.

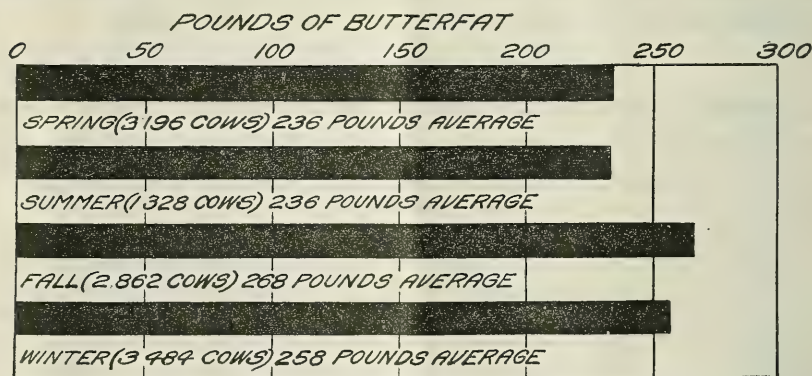


FIG. 1.—Relation of butterfat production to season of freshening.

The cows that freshen in the fall not only rank first in yearly butterfat production, but they produce most during the winter months. In many parts of the country the dairyman has more time in winter to do the extra work connected with their feed and care.

It is also true that fall-freshening cows are dry at the time of year when field work is generally greatest.

FEED COST.

The cost of roughage was about the same regardless of the season of freshening, but there was a considerable difference in the cost of grain. Table 5 shows how the four seasons ranked on average cost of grain per cow; that is, the year's cost of grain for cows of the different seasons.

TABLE 5.—Seasons when cows freshened ranked according to cost of grain required for the year's feed.

Season of freshening.	Number of times ranked.			
	First.	Second.	Third.	Fourth.
Spring.....	6	5	12	41
Summer.....	9	15	23	15
Fall.....	44	14	5	1
Winter.....	5	30	24	5

In 44 of the 64 associations fall freshening ranked first in cost of grain to feed a cow a year and in only one of the 64 associations did the fall-freshening cows rank fourth in cost of grain. On an average the cost of grain was highest for the cows that freshened in the fall (see Table 1), next highest for those that freshened in the winter, and lowest for those that freshened in the spring. The average cost of grain per cow was lowest in 41 of the 64 associations for the cows that freshened in the spring.

As the cost of roughage for the year was about the same regardless of the date of freshening, the total cost of feed varied approximately according to the cost of grain. Table 6 shows how the seasons ranked on total cost of feed.

TABLE 6.—Seasons when cows freshened ranked according to total cost of feed.

Season of freshening.	Number of times ranked.			
	First.	Second.	Third.	Fourth.
Spring.....	8	5	11	40
Summer.....	9	14	24	15
Fall.....	42	18	3	1
Winter.....	5	27	26	6

In 8 associations the feed cost was greatest for the cows that freshened in the spring, in 9 the feed cost was greatest for those that freshened in the summer, in 42 the feed cost was greatest for those

that freshened in the fall, and in 5 the feed cost was greatest for those that freshened in the winter. Referring to Table 1 we find that in all the associations combined and over a period of years the average cost of feed for the cows that freshened in the fall was \$67.39; for those that freshened in the winter, \$63.16; for those that freshened in the summer, \$60.10; and for those that freshened in the spring, \$56.73. In practical application the figures should be considered as relative, not absolute. These variations are not great when averages are considered, but they are much greater for some associations and very much greater for single herds in some associations. Where pastures are good and cheap the summer feed cost is low, and where pastures are poor and hard to get the summer feed cost is relatively high.

INFLUENCE OF PASTURE ON FEED COST.

To determine the influence of good pastures on production and income, a comparative study was made of one year's records of two cow-testing associations in the same State and not far apart. For convenience we will call these associations A and B. Association A had good pastures and association B had relatively poor pastures.

In association A the feed cost was greatest for the cows that freshened in the fall, their yearly milk production averaged 446 pounds less and their yearly butterfat production averaged 12 pounds less than those that freshened at other seasons of the year. In income over cost of feed they fell \$17.88 behind the average of those that freshened in the summer and \$25.97 behind those that freshened in the spring. In income over cost of feed the figures were as follows: Spring freshening, \$94.83; winter freshening, \$91.67; summer freshening, \$86.74; and fall freshening, \$68.86. The figures for that association were decidedly against fall freshening, but these results were the exception and not the rule when all the 64 associations were considered.

In association B, where the pastures were poor, feed cost was also greatest for the cows that freshened in the fall, but these cows, as well as those that freshened in the winter, were ahead in production of milk and butterfat and in income over cost of feed. In income over cost of feed the figures for association B (having the poor pastures) were as follows: Fall freshening, \$86.18; winter freshening, \$85.99; spring freshening, \$82.02; and summer freshening, \$81.73.

For association A the average income over cost of feed was \$85.59 and for association B it was \$84.26. The figures do not prove that dairying is more profitable where pastures are good, but they furnish some evidence that the question of pasture should have weight in determining the time of year when it will pay best to have cows freshen. Labor, too, must be considered.

On account of labor and miscellaneous expenses the income over cost of feed is not all net profit in the dairy business, but it is from the income over cost of feed that net profit is obtained. So far as possible, the dairyman should aim to have his cows freshen at the time of year that will bring him the greatest net return. That may or may not be the date of freshening that gives the greatest income over cost of feed. Income over cost of feed is only one of the factors that give net profit, but it is one of the most important. Labor is also a very important factor, but cow-testing records do not furnish data regarding labor costs.

INCOME ABOVE FEED COST.

According to Table 1 fall freshening ranks first in income over cost of feed; winter, second; spring, third; and summer, fourth. There was not much difference, however, between fall and winter freshening in this important respect. For the four seasons the average income over cost of feed for the 64 associations was as follows: Fall freshening, \$76.65; winter freshening, \$75.66; spring freshening, \$70.73; and summer freshening, \$66.59.

In Table 7 the seasons are ranked with reference to the relation of date of freshening to income over cost of feed per cow.

TABLE 7.—Seasons ranked according to relation of date of freshening to income over cost of feed.

Season of freshening.	Number of times ranked.			
	First.	Second.	Third.	Fourth.
Spring.....	9	8	21	26
Summer.....	8	10	17	27
Fall.....	30	24	7	3
Winter.....	17	23	18	6

The table shows the number of times each of the four seasons ranked first, second, third, and fourth on income over cost of feed. Fall ranked first 30 times and fourth only 3 times. Winter ranked first 17 times and fourth only 6 times. Spring ranked first 9 times and fourth 26 times, while summer ranked first 8 times and fourth 27 times.

INFLUENCE OF MONTH OF FRESHENING.

Table 8 shows the relation between month of freshening and milk production, butterfat production, gross income, and income over cost of feed of the same cows previously discussed under seasonal influences.

TABLE 8.—*Month of freshening in relation to average annual production and income per cow.*

Month of freshening.	Number of cows.	Milk production.	Butterfat production.	Gross income.	Income over cost of feed.
		<i>Pounds.</i>	<i>Pounds.</i>		
January.....	1,209	6,416	256	\$137.64	\$74.98
February.....	1,185	6,164	250	131.24	71.43
March.....	1,472	5,962	241	129.80	72.51
April.....	1,047	5,698	231	126.55	70.21
May.....	677	5,800	232	123.77	67.65
June.....	460	5,717	224	123.81	65.61
July.....	396	5,864	233	123.06	63.93
August.....	472	6,225	250	132.54	69.77
September.....	779	6,408	259	137.97	72.91
October.....	1,016	6,865	274	148.33	79.04
November.....	1,067	6,727	271	144.38	77.10
December.....	1,090	6,764	268	148.38	81.01
Total and averages.....	10,870	6,269	252	135.37	73.36

The cows that freshened in September, October, November, December, and January averaged high in production of both milk and

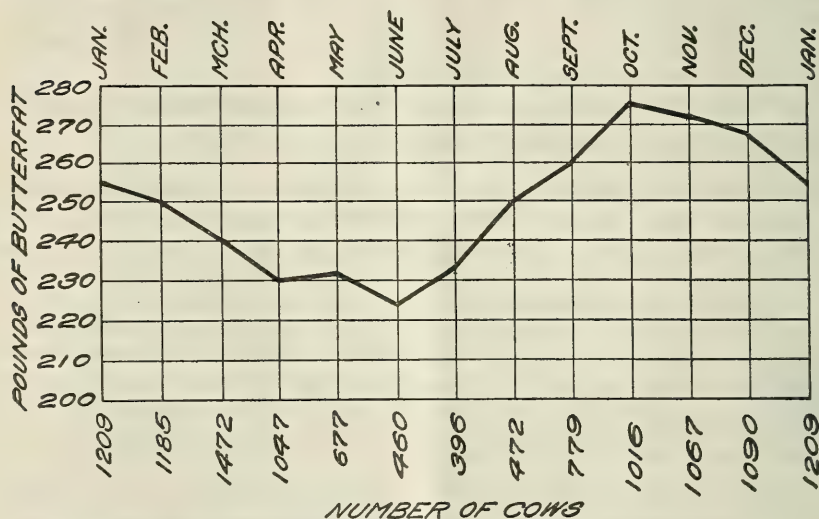


FIG. 2.—Relation of butterfat production to month of freshening.

butterfat. For each of these five groups the average butterfat production was above 250 pounds, but for cows that freshened during other months the average butterfat production never went above 250 pounds. The cows that freshened in April, May, June, and July were lowest in average production of butterfat and those that freshened in July had the lowest average income over cost of feed.

Figure 2 shows graphically the average production of butterfat per cow according to month when cows freshened.

Considering butterfat production alone, October freshening ranks highest for the 64 associations, although November, December, September, and January are not far behind. The regularity with which

yearly butterfat production went down as the date of freshening approached midsummer is only a little less marked than the regularity and rapidity with which yearly butterfat production went up as the date of freshening advanced from June to October. It must be remembered that these figures are the averages for 64 associations and that they do not hold true for every one of the associations.

HOW THE MONTHS RANKED.

Table 9, which was made from the averages of the 64 associations, shows that the cows that freshened in the fall and winter months ranked high in production of milk and butterfat and in income over cost of feed.

TABLE 9.—*Months when cows freshened ranked from 1 to 12 on yearly records of production, costs, and income.*

Month.	Milk production.	Butterfat production.	Value of product.	Cost of roughage.	Cost of grain.	Total feed cost.	Income over cost of feed.
January.....	4	5	5	7	5	6	4
February.....	7	6	7	12	7	7	7
March.....	8	8	8	8	10	10	6
April.....	12	11	9	6	12	11	8
May.....	10	10	11	11	11	12	10
June.....	11	12	10	8	9	9	11
July.....	9	9	12	10	8	8	12
August.....	6	6	6	5	6	5	9
September.....	5	4	4	4	4	4	5
October.....	1	1	2	1	1	1	2
November.....	3	2	3	3	2	3	3
December.....	2	3	1	2	3	2	1

On every topic in this table the three months October, November, and December won the first three ranks, though not always in the same order. This indicates that, on an average, it generally pays to have cows freshen in the fall and early winter. Though they eat more grain, the greater production generally gives them an advantage all along the line.

CONCLUSIONS.

The study that has been made of the records from 64 cow-testing associations shows that fall or early winter freshening is desirable in most parts of the country. The influence of season of freshening is important, but the dairyman who has a steady market for milk at fair prices during all seasons of the year will usually find it to his advantage to keep the supply of dairy products fairly uniform from month to month.

Often the results due to date of freshening are different in different associations, even in the same agricultural district. For that reason no set rule can be given as to what percentage of the cows should freshen each month in the year. That will vary to some

extent in different localities and on different farms in the same locality. At the present time in market-milk districts there is generally a surplus of milk in the late spring and early summer. For that reason, if for no other, the dairy business should be so managed as to have more cows freshen in the fall. Such a practice would add to the profits of the producer, give the consumer a more constant supply of dairy products, and bring about a better distribution of farm labor throughout the year.

SUMMARY.

1. The tabulation includes the yearly records of 10,870 cows in 64 cow-testing associations.

2. On an average the cows that freshened in the fall produced 6,689 pounds of milk, while those that freshened in the winter, summer, and spring produced 6,439, 5,941, and 5,842 pounds, respectively.

3. On an average the cows that freshened in the fall produced 268 pounds of butterfat, while those that freshened in the winter, spring, and summer produced 258, 236, and 236 pounds, respectively.

4. On an average the cows that freshened in the fall returned \$76.65 in income over cost of feed, while those that freshened in the winter, spring, and summer returned \$75.66, \$70.73, and \$66.59, respectively.

5. In the 64 cow-testing associations fall freshening ranked first 29 times in average milk production, winter freshening ranked first 18 times, summer freshening 10 times, and spring freshening 7 times.

6. In butterfat production fall freshening ranked first 38 times, winter 13 times, summer 8 times, and spring 7 times.

7. In income over cost of feed fall freshening ranked first 30 times, winter 17 times, spring 9 times, and summer 8 times.

8. In considering the months separately the cows that freshened in October ranked first in production of milk, those that freshened in December ranked second, and those that freshened in November ranked third.

9. In butterfat production October freshening ranked first, November second, December third, and September fourth.

10. In income over cost of feed December freshening ranked first, October second, November third, and January fourth.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1072



Washington, D. C.

June 17, 1922

THE HANDLING, SHIPPING, AND COLD STORAGE
OF BARTLETT PEARS IN THE PACIFIC COAST
STATES.¹

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INTRODUCTION.

During recent years there has been a very considerable increase in the acreage devoted to the growing of pears on the Pacific coast. These plantings have been distributed in various parts of California, Oregon, and Washington. Careful estimates indicate that the production of pears will increase fully 50 per cent within the next five or six years.

Of the varieties of pears grown on the Pacific coast the Bartlett far outranks all others combined. It is a safe estimate that more than 50 per cent of all pears grown in Washington and Oregon are of this variety, while in California, the heaviest pear-producing State in the Union, probably 75 per cent of all pears grown are Bartletts. Furthermore, although the so-called winter varieties, coming into market following the Bartlett season, are increasing in popularity in some of the cooler growing sections, the Bartlett is practically the only variety being planted in large quantities in those districts in which it reaches its highest quality.

¹ This bulletin gives the result of a portion of the work carried on under the project "Factors Affecting the Storage Life of Fruit."

The reason for the popularity of the Bartlett variety is readily understood. A very heavy bearer of fruits of large size and of very high dessert quality, it is the ruler of the fresh-pear markets during the weeks in which it is in season. Where canned it has a higher quality than any other pear and in regions where it can be produced successfully is practically the only variety that goes into the commercial canned-fruit trade. In some districts it is also dried very successfully, and a large demand has been created for the dried product.

With the constantly increasing production of Bartletts, however, it has become apparent that some means of holding the fruit in cold storage is vital to the industry in many producing sections. If the total season for fresh consumption can be lengthened by several weeks, a much larger quantity of fruit can be disposed of on the fresh-fruit market.

It is even more important that canners in certain sections be able to hold the fruit in storage. In some sections Bartlett pears and certain varieties of peaches reach canning condition at practically the same time. Since pears can be held more successfully than peaches, it is of great advantage to put a portion of the pears in cold storage and hold them until the peach-canning season is over. It also reduces the overhead expense of the cannery to prolong the canning season as much as possible. In former years heavy losses have been suffered by some pear canners, owing to fruit becoming overripe during the rush season. Much loss has also occurred in fruit that has been in cold storage, due to improper methods of handling.

During the past two seasons investigations have been carried on by the Bureau of Plant Industry to determine (1) the effect of the time of picking on the keeping, eating, and canning quality of Bartlett pears, (2) the comparative keeping and carrying capacity of fruit from different sections of the Pacific coast grown under widely varying climatic conditions, and (3) the method of handling fruit in cold storage which will give the longest keeping period and the highest dessert quality in the fruit upon removal from cold storage. Chemical and physiological studies have been made of fruit from different sections gathered at different stages of maturity and held under different conditions following picking. The results of some of these studies have been presented in detail in an earlier publication.² It is the primary purpose of this bulletin to discuss the results presented in that report, as they concern the practical grower and handler of Bartlett pears, and also to include the results of some additional investigations.

² Magness, J. R. Investigations in the ripening and storage of Bartlett pears. *In* Jour. Agr. Research, v. 19, no. 10, p. 473-500, 8 fig. 1920. Literature cited, p. 499-500.

DISTRIBUTION OF BARTLETT PEAR GROWING IN THE PACIFIC COAST STATES.

In California Bartlett pears are grown under a very wide range of climatic conditions. By far the heaviest producing area lies along the Sacramento River on reclaimed land below the city of Sacramento. This region produces about one-third of all the pears grown in the State. Another heavy-producing section lies in the foothills of the Sierra Nevada Mountains north and east from Sacramento and centering about the towns of Newcastle, Auburn, Colfax, and some others. This area lies in Eldorado, Nevada, and Placer Counties, mainly in the last. A third important region is the Santa Clara Valley, centering about San Jose. There are, however, large plantings of pears in all the region centering about San Francisco Bay, from 150 miles north of San Francisco to 100 miles south and east to the Sierra Nevada Mountains. Some sections of southern California are also beginning to produce pears extensively. Los Angeles County has a large acreage soon to come into bearing and is already a factor in the tonnage produced. The Antelope Valley, at the edge of the Mojave Desert, has a considerable acreage of pears, while at Tehachapi, at the summit of the range of mountains of that name, is another fairly large area. These regions in southern California are not yet in full bearing.

In Oregon the principal pear-producing section is in the Rogue River Valley, in the southwestern part of the State. A large tonnage is also produced, however, throughout all the valleys of the western part of the State, particularly in the Willamette Valley, about Salem. The Hood River Valley is also growing pears in important commercial quantities.

The Yakima district is by far the heaviest pear-producing section of Washington. The Wenatchee district is second in total tonnage, while scattered plantings occur through the other fruit sections.

There is wide variation in the method of handling fruit from these different sections. Some growers depend entirely upon the shipment of fresh fruit to the Eastern States in order to market their crop. In other sections the canneries are depended upon entirely as an outlet for the production. The crop from numerous sections is shipped in part in the fresh state, the remainder usually being canned, while the output of at least one important producing section (Lake County, Calif.) is practically all dried.

HANDLING FRUIT FOR SHIPMENT IN A FRESH STATE.

TIME OF PICKING.

One of the most important questions which face the grower or the shipping organization is that of knowing when to pick the pears. Wide differences of opinion prevail as to the effect upon the keeping quality of the fruit of leaving it on the trees until late or of removing

it from the trees early. In the present practice the size of the fruit is the most important consideration in determining when to pick.

In the investigations here recorded special attention has been paid to the time of picking the fruit. Pickings of pears have been made at intervals beginning before the commercial season started and continued until some time after it was over. Observations of the fruit have been supplemented by chemical studies, the results of which have been presented in a previous report.³ Tests of the output of carbon dioxid from the fruit following picking at different stages of maturity and under different temperatures of storage have also been made and will be reported in detail in a separate publication. The exact analyses upon which many of the conclusions reached in this report are based have been presented in detail in the paper mentioned.

There is no fixed time at which it may be said that pears are in just the right condition to pick. The time of picking will vary widely with the manner in which the fruit is to be marketed.

If removed from the trees too early, Bartlett pears will tend to shrivel and wilt before ripening. It has been found that the time at which the fruit may be picked without danger of wilting can be determined by testing for the corking over of the lenticels.

As the fruit grows, numerous small light-colored spots can be observed all over its surface. Examination under the microscope reveals the fact that these are minute openings through the skin of the fruit. These lenticels, as they are called, are open during the early growth of the pears. If such a fruit be immersed in a strong solution of methylene blue in water and left for 15 minutes to half an hour, these spots will be colored a deep blue by the stain that has penetrated the tissue. About the time shipping usually commences, however, the lenticels become brown, owing to the formation of a layer of corklike cells over the surface of the opening. After this forms, if the fruit is immersed in the methylene-blue solution, the stain penetrates very little. When the fruit is removed from the stain and rinsed, the methylene blue can be detected only as a faint, thin ring about the outside of the lenticel. The stain will not penetrate the corky layer. Although it has never been tested, it is extremely probable that ordinary laundry bluing, made up in a strong solution, would serve the purpose as well as methylene blue.

After the lenticels are once sealed over, there is little further danger of the fruit shriveling after removal from the tree, and if it has attained sufficient size it can be picked with safety. It has been found, however, that if the fruit is left on the tree for about two weeks longer, a very much superior product will be obtained. The sugar content increases rapidly during this period, and the fruit is

³ Magness, J. R. Op. cit.

much higher in dessert quality if removed from the tree two to three weeks following the corking over of the lenticels rather than immediately thereafter. The earliest Bartlett pears to arrive on the eastern markets are almost invariably of very poor quality, owing to too early picking.

It has been found, however, that at the temperatures it is possible to maintain in a car during transit, Bartlett pears will arrive on the market in a greener condition if picked early. The fruit trade at the present time demands that pears show mainly green color upon arrival, and with this fact in mind, picking, especially in districts where considerable difficulty is experienced in getting fruit to carry through to market, can not be delayed too long.

It has also been found, however, that late-picked fruit will hold up for a much longer period after it becomes soft and in an edible condition than fruit from the same trees picked early. With the early-picked fruit there is a period of only two or three days during which the pears are in a good edible condition, while fruit from the same trees but picked three to four weeks later will remain in good, firm condition four to five days after becoming soft enough for eating. In districts where little difficulty is experienced in shipping fruit to market, a much larger sized fruit, of higher dessert quality, and one that will hold up longer for the retail trade, can be secured by delaying the initial picking until about 10 days later than is the present practice.

RELATION OF THE CARRYING QUALITY OF BARTLETT PEARS TO THE CLIMATIC CONDITIONS UNDER WHICH THEY ARE GROWN.

During the progress of this work a very careful study has been made of the keeping and carrying quality of fruit from some of these different regions. This study has been supplemented by discussions with some of the leading producers and shippers from each of the various districts. There are wide variations in the climatic conditions under which Bartlett pears are grown in the Pacific Coast States, and these are reflected in equally wide variations in the keeping and carrying quality of the fruit following its removal from the trees.

In Bartlett pears that are apparently in the same state of maturity at the time of picking, there is a marked difference in the number of days required for the fruit from different producing sections to become ripe after removal from the trees. Fruit from some sections requires 12 to 14 days when picked at the height of the season and held at temperatures of 60° to 70° F. following picking before it is in prime condition for eating. Such fruit is usually of a close-grained texture, rather firm when fully ripe, and ripens evenly throughout the whole fruit.

The fruit from some other sections becomes soft ripe much more quickly, even when picked in what is apparently the same stage of maturity and held at the same temperature following picking. This latter type of fruit is usually rather coarse in texture, softer when ripe than the slower ripening pears, and has a marked tendency to become overripe and discolored about the core region while the outside of the fruit appears to be entirely sound. Such fruit from many sections has been found to ripen in so short a time after picking that successful shipments of the fresh pears to eastern markets is impossible. In certain districts canners, unfamiliar with the tendency of the fruit to become overripe at the core before showing external signs of deterioration, have suffered heavy losses by allowing the pears to remain too long before canning.

Canners and pear shippers are fully aware of the wide variation that occurs in the carrying qualities of the pears from different sections, at least in so far as these variations occur in their local territory. It is believed, therefore, that a discussion of the ripening of the fruit as it occurs in the different districts will be of advantage not only to the industry as a whole, but also to all the individual districts. For although fruit from certain districts will ripen more evenly and hold up longer following removal from the tree than that from other sections, there is no place on the Pacific coast where Bartlett pears are grown commercially that they can not be handled successfully, at least for canning or drying, provided proper precautions are taken.

It has been found that Bartlett pears from the Sierra Nevada foothill region east of Sacramento have uniformly excellent carrying and keeping qualities. The same may be said for pears from most of the districts in southern California, particularly the Tehachapi and Antelope Valley plantings. Fruit from the upper Sacramento Valley is very high in carrying quality. In the very large Bartlett pear section, lying along the reclaimed lower Sacramento River, the fruit is also of high carrying quality, although some trouble is encountered with pears from the lower part of this section nearest the coast.

In the Santa Clara Valley the fruit is much poorer in keeping and carrying quality, and fresh shipments from this district have been largely discontinued because of the difficulty in getting the pears through to market in good condition and the excellent cannery market available.

The Bartlett pears grown in the counties bordering on the coast in California are uniformly poor in carrying quality. They become soft ripe quickly after removal from the tree and have a marked tendency to soften and become overripe at the core while still apparently firm on the outside.

In Oregon the Rogue River Valley Bartletts carry the best of any in that State and are comparable to the Sacramento River fruit. Pears from the Salem district ripen quickly and must be handled more promptly after the removal from the tree. In Washington much difficulty has been experienced in handling Bartletts from the Yakima and Wenatchee Valleys for eastern shipment. The fruit ripens rapidly and has a tendency to ripen first at the core. By using the best methods of precooling, shippers have been successful in handling the fruit from the Yakima Valley, though severe losses are still encountered in attempting to ship the Wenatchee grown Bartletts to eastern markets.

From a survey of the fruit as grown under the widely varying climatic conditions of the Pacific coast, it is apparent that a marked relationship exists between the keeping quality of Bartlett pears following their removal from the tree and the summer temperatures under which the fruit is grown. These observations have been made entirely in the pear regions on the Pacific coast, and no attempt has been made to check them by tests in the eastern producing States.

The records of the United States Weather Bureau for various points in each of the main Bartlett pear-producing sections have been obtained, and from these records the average daily maximum and minimum temperatures for June, July, and August have been computed. These records are averages for a large number of years. The temperature records together with notes on the carrying quality of the fruit following removal from the tree are summarized in Table 1.

In certain instances it has been impossible to secure Weather Bureau records of the average daily maximum and minimum temperatures directly in the main pear-producing regions. However, it has been possible to obtain data sufficiently complete to give a very good idea of the general temperature range. As these studies have been carried on, it has become increasingly evident that the summer growing-season temperatures are of great importance in the development of fruit that has a long keeping season.

Bartlett pears grown in the Antelope Valley and other very hot districts in California have a widely known reputation for keeping quality. Often the summer temperatures in this region run to 115° F. The upper Sacramento Valley and foothills of the Sierra Nevada Mountains, also having high temperatures during the growing season, produce pears that can be shipped to any point in the United States. Such fruit is loaded into iced refrigerator cars, shipped without previous precooling, and unless unexpected delays occur usually arrives on the markets in excellent condition.

Pears from the lower Sacramento Valley, in the region between Sacramento and the mouth of the river, are also very good shippers, although occasional trouble is encountered. This is especially true of fruit from the lower and cooler portion of this region. In this

lower valley region fruit is sometimes found breaking down at the core while still sound at the surface, but this tendency is not common in fruit from this section.

TABLE 1.—*Relation between the shipping quality of Bartlett pears from different districts and the temperature conditions under which they are grown.*

District and station.	June.		July.		August.		September.		Remarks.
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	
Antelope Valley, Calif.: ¹	-----	-----	-----	-----	-----	-----	-----	-----	Fruit of very highest keeping and shipping quality.
Upper Sacramento Valley:									
Chico.....	89.3	55.0	98.9	60.2	97.4	58.3	-----	-----	Fruit of excellent keeping and carrying quality.
Red Bluff.....	87.8	61.6	94.7	66.3	95.1	65.1	-----	-----	
Marysville.....	87.9	58.0	95.8	60.8	94.6	59.5	-----	-----	
Sierra Nevada foothills:									
Rocklin.....	86.0	52.7	94.7	58.8	94.2	57.3	-----	-----	Fruit ripens evenly and is of firm texture.
Auburn.....	85.1	55.0	91.7	61.1	91.8	60.3	-----	-----	
Lower Sacramento Valley: ²									
Sacramento.....	82.3	56.2	88.8	58.2	88.8	57.7	-----	-----	Occasionally fruit becomes overripe in transit east, particularly from the lower and cooler portions of this region.
Lake County, Calif.:									
Upper Lake.....	83.5	50.0	93.2	54.4	92.9	52.6	-----	-----	Fruit holds up well and ripens evenly.
Rogue River Valley, Oreg.: ³									
Ashland.....	76.3	47.0	86.2	51.9	85.4	51.5	-----	-----	Considerable difficulty during certain seasons from fruit breaking down in transit.
Yakima, Wash.:									
Moxie.....	80.9	48.0	88.9	53.1	87.4	51.1	77.3	42.4	Great difficulty in shipping; careful precooling necessary.
Wenatchee, Wash.:									
Wenatchee.....	74.9	49.0	83.7	55.8	81.0	54.6	71.4	47.6	Tendency to break down at core.
Santa Clara Valley, Calif.:									
San Jose.....	76.9	48.7	80.9	52.0	79.9	51.3	-----	-----	Fresh eastern shipments practically abandoned because of breaking down in transit.
Santa Clara.....	77.0	46.5	82.5	50.6	81.5	49.6	-----	-----	
Sonoma County, Calif.:									
Santa Rosa.....	77.9	45.8	82.0	49.1	82.1	47.1	-----	-----	About the same as Santa Clara Bartletts.
Willamette Valley, Oreg.:									
Salem.....	72.1	49.7	79.6	53.3	80.1	53.1	-----	-----	Little attempt made to ship to eastern markets. Canneries take total crops.
California coast district:									
Oakland.....	72.7	52.7	73.0	53.8	70.2	54.3	-----	-----	Fruits very poor keeping; marked tendency to break down inside; Santa Cruz County (Watsonville) Bartlett especially bad.
Watsonville.....	68.0	47.7	68.1	47.0	68.2	45.5	-----	-----	

¹ The temperature record is not available, but the summer range is the highest of any place listed.

² The main pear district is somewhat cooler than Sacramento. Records are not available.

³ The main pear district is at a much lower elevation and is warmer than the above records show.

The Rogue River Valley district in southern Oregon produces a good-shipping Bartlett pear, though considerable fruit arrives on the markets in an overripe condition. This fruit approximates that from the lower Sacramento Valley in carrying quality, but somewhat more trouble is experienced with it, owing to a longer haul to market. Most of this fruit goes east via Sacramento. The temperatures given for this district are for Ashland, a markedly cooler location than the main pear plantings centering about Medford.

In the Yakima and Wenatchee districts of Washington very great difficulty has been experienced in shipping fruit through to eastern markets. In former years the losses from fruit breaking down in transit were very heavy. By prompt and very efficient precooling, however, it has been possible to handle the Yakima Valley fruit during recent years without much loss. The Wenatchee Valley, with a somewhat cooler growing season and less cold-storage capacity for precooling, still suffers considerable loss of Bartlett pears on eastern shipments.

The temperature range in these districts (the Yakima and Wenatchee Valleys) is not markedly lower than that at Sacramento. It is true, however, that during a normal season the peak of the picking season in the former regions is not reached until the first week in September. It will be noted that September temperatures represent a sharp drop below those of July and August. This may account in part for a greater difficulty with this fruit than the records would seem to warrant.

In the Santa Clara Valley of California, centering about San Jose, in the Sonoma County section north of San Francisco, and in the Willamette Valley of Oregon attempts to ship Bartlett pears to eastern markets have not generally met with success, except in the case of very early picked fruit. These districts, near enough to the coast to have a comparatively cool climate, produce Bartletts excellent for cannery purposes, but with a carrying season too short to allow them to be readily handled for eastern shipment. The tendency to break down internally is marked. It is probably true, however, that some of this fruit, even of later pickings, could be shipped successfully were it possible to precool it efficiently.

In the counties near the coast, and especially in districts directly adjacent to the coast, a few Bartlett pears are produced. Grown in this extremely cool climate, the pears are of the poorest keeping quality of any under observation. Such fruit is particularly likely to break down internally, and it must be handled very carefully, even for use by canneries, if it is to be utilized without loss.

It is not the intention in this report to imply that the temperature of the growing season is the only factor involved in determining the rapidity of the breakdown in pears following removal from the tree. In the territory studied the humidity varies inversely with the temperature, the regions of high temperature being low in humidity, and vice versa. This may be equally important with temperature in its effect on the fruit. Soil and soil moisture undoubtedly are factors entering into the keeping quality of the fruit to a marked extent, but the relationship to temperature during the growing season seems to stand out when the conditions characterizing the different districts are considered.

Observations indicate that this same relationship of temperature and humidity during the growing season to keeping quality holds in regard to many other deciduous fruits, though not necessarily in the same degree as with Bartlett pears. Plums, prunes, cherries, apricots, and other fruits seem to show a similar tendency toward poor keeping quality when grown under particularly cool conditions, but they have not been studied in sufficient detail to warrant a definite statement.

MARKETING BARTLETT PEARS FROM DIFFERENT DISTRICTS.

The trade, through long experience in handling fruit from different sections of the country, has become thoroughly acquainted with the characteristics of pears from different regions. Consequently, the fruit is now utilized largely in the manner to which it is best adapted.

Fruit dealers in the districts in which the pears produced are of the highest carrying quality usually ship the bulk of their crop to eastern markets. In some regions the early-picked fruit is shipped, but the later picks, which are of poorer carrying quality, are marketed through the canneries. In the coolest regions no attempt is made to ship Bartletts any great distance. They are sold to canneries or marketed locally.

PRECOOLING PEARS FOR SHIPMENT.

The advisability of precooling Bartlett pears before shipping is one that varies greatly with the particular district under consideration and with the facilities that are available for cooling the fruit. By precooling is meant placing the fruit in a cold-storage room and cooling it thoroughly before loading it into a car or holding a car of fruit on a siding adjacent to a plant equipped to circulate cold air through the car, thus cooling the fruit more quickly than is possible by simply placing ice in the car.

In those districts in which little difficulty is experienced in getting fruit through to market there is no reason for departure from the present practice. The fruit should be packed as promptly as possible after removal from the tree, loaded into iced refrigerator cars, and started to market at once. At the present time the railroad tariffs allow the addition of salt to the ice in the cars, which greatly hastens cooling. Tests carried on by the Office of Preservation of Fruits and Vegetables in Transit and Storage of the Bureau of Markets and Crop Estimates, United States Department of Agriculture, have shown that 200 pounds of salt added to the ice in each bunker at the time of loading is of very great value in quickly cooling the fruit to the minimum temperature that it is possible to maintain in the car.

In shipping fruit from districts in which pears have poor carrying qualities, precooling has proved of great value in putting the fruit on the market in good condition. The success or failure of precooling will depend, however, primarily upon the answer to one question,

namely, how soon after the removal of the fruit from the tree can the pears themselves be cooled to 30° F. or below? If the fruit after picking can be reduced to this temperature in 24 to 36 hours, there is no doubt that such treatment will be of great advantage in the shipping of the fruit.

Such results can be attained, however, only by having a very large refrigeration capacity in proportion to the quantity of fruit handled. Marked success has been attained by precooling in the Yakima Valley in Washington, and an outline of the methods followed there will indicate the procedure that has given greatest success in handling Bartlett pears.

The rooms in which the pears are to be placed are cooled to below 28° F., in many cases the temperature being reduced to 10° to 20° F. before the fruit is brought in. The fruit is taken to the storage house in lug boxes immediately after picking. As it cools, the room temperature rises, but the air in the rooms is kept down to 28° F. or is again reduced to that temperature as quickly as possible after the fruit is placed in the room. After 36 to 48 hours at 28° F. the fruit is removed to a warmer room, held at about 40°, where it is graded, packed, and quickly returned to the 28° room. In most cases the fruit is not in the packing room for more than 30 minutes to an hour, and it is probable that the temperature of the fruit itself does not rise more than 1 or 2 degrees during this time. The fruit is shipped at any time after packing, from immediately thereafter up to a month later. The bulk of the crop, of course, is forwarded at once.

Pears cool very slowly when taken into cold storage, and at least 24 hours will be required to reduce the unwrapped fruit in boxes to the desired temperature. If the fruit is wrapped before cooling or if the boxes are closely stacked in the rooms, a much longer time is required, due to the insulating effect of the paper and the reduced aeration in the boxes. In this connection the need for an armored thermometer that can be inserted in the fruit itself, by means of which its temperature can be determined, should be emphasized. Low temperatures retard the ripening processes in the pears only after the fruit itself reaches that lower temperature. This is very often a considerable time after the air is at the desired temperature; this is doubly true if the fruit is wrapped.

Very careful tests have been made of the rate of ripening of Bartlett pears at different temperatures by measuring the carbon dioxid given off by them. It has been found that they ripen about twice as rapidly at 37° F. as at 30° F. It is not possible to stop entirely the ripening of the fruit at any temperature above the freezing point, which in Bartlett pears has been found to be between 27° F. and 28° F. However, at temperatures under 30° F. the fruit ripens so slowly that a number of days at this temperature makes only a slight difference in the time the pears will hold up after removal from cold storage.

In the districts where difficulty is experienced in keeping fruit shipped to eastern markets in good condition, precooling, when carried on as outlined above, has proved to be of great advantage. In some instances, however, commercial precooling has failed to give satisfactory results. The cause of this has invariably been the failure to cool the fruit in a limited time. Overtaxing the refrigeration capacity of the plant or attempting to cool closely stacked boxes of wrapped and packed fruit has in many cases resulted in a rate of cooling so slow that the injury caused by delay incident to the cooling has been greater than the benefits gained. Since ripening goes on until the fruit is actually reduced to the minimum temperature, a delay incident to cooling is as serious as a delay while the fruit is en route. If shipment is delayed without actually getting the fruit cooled through and through, the results will be less satisfactory than if the pears are shipped immediately after picking.

HANDLING FRUIT FOR THE CANNERIES.

The handling of Bartlett pears for the cannery is quite different in the ultimate object to be attained from the handling of the same commodity for shipment in a fresh state. With the cannery man a fruit of high dessert quality is the first consideration. The number of days that must elapse between the time of picking and the time the fruit is in prime condition for canning is of less importance than the number of days during which the fruit may be canned or, in other words, between the time when the fruit becomes soft ripe and the time when it begins to break down. There is no doubt that the consumption of canned pears would be greatly increased if all this fruit that goes on the market was of the high quality found in certain cans. There is also no doubt that the greatest factor in the production of canned fruit of low eating quality is the inferiority of the fruit itself before canning. With proper handling there will be no occasion for much of the low-grade product that now goes into cans in many plants.

Perhaps the greatest single cause of poor quality in canned Bartlett pears is picking the fruit too early. There is a marked increase in sugar in fruit taken from the tree at successive intervals during the commercial picking season. During a delay of two weeks in picking the sugar content of the fruit will often increase by 10 per cent. In addition to the increase in sugar, late-picked pears lose much of the astringency characteristic of fruit picked early in the season. The highest quality in Bartlett pears is not attained until the fruit is showing a distinct tinge of yellow color beneath the green at the time of its removal from the tree. Such fruit, if held at temperatures of 60° to 70° F., will be in good condition for canning comparatively soon after removing it from the tree. The exact time will vary with the section in which the fruit is grown. After

ripening, however, this same fruit will remain firm and without decay for several days, giving a long period in which to put the fruit into the cans.

It is obvious, however, that if the pears are left on the trees until late in the season the cannery will have a large quantity of fruit to handle within a comparatively short time. In many cases this can be remedied only by putting the fruit, or a portion of it, into cold storage and holding it there until such time as it can be utilized to advantage.

THE COLD STORAGE OF BARTLETT PEARS.

The cold storage of Bartlett pears has passed the experimental stage, and it only remains for handlers to adopt the best methods in order to obtain a high-grade stored product. This variety of pear has been held in commercial storage for a period of three months, and in experimental storage up to five months, practically without loss.

The two factors which in the past have been responsible for the greatest loss to pear-storage men are (1) allowing the fruit to become too nearly ripe after removal from the tree before putting it in storage and (2) holding the storage rooms at too high a temperature. To these should be added a third factor, namely, pear storage scald. These factors will be discussed individually.

If fruit is to be held in cold storage it is essential that it be placed in the storage rooms as soon as possible after removal from the tree. It is impossible to stop entirely the ripening processes going on in fruit by cold storage, though the rate of ripening can be so reduced that several months will be required to attain the same degree of ripeness that would be reached in 10 days to two weeks at ordinary temperatures. In storing for a cannery the fruit should be placed in storage immediately after removal from the tree for the best results. This is especially the case if fruit from districts producing pears of very poor keeping quality is being stored. This fruit, if left on the tree until in the best condition for canning, will ripen within three or four days after removal from the tree. Such fruit should be in storage within 24 hours at the maximum from the time of picking and preferably on the same day it is picked. This is possible only if the storage house is within trucking distance of the orchard.

STORAGE TEMPERATURE.

Commercial experience, as well as detailed tests by the Bureau of Plant Industry, have shown that for the best results in cold storing Bartlett pears the temperature should be 30° F. or slightly below. This is the temperature that has been found best in the Yakima Valley district in Washington, where fruit handlers have had the widest experience in the commercial cold storage of Bartletts of any section in the Pacific Coast States. As mentioned earlier in this report, it

has been found that Bartlett pears respire about one-half as fast at 30° F. as they do at 37°. The average respiration rate at 60° F. is about 10 times that at 30°. It has also been found that fruit can be held fully 10 times as long in storage at 30° as at 60° F.

Fruit when held in cold storage until full yellow and soft is invariably of poor dessert quality. It is flat in taste and lacking in flavor. Apparently such fruit has not developed many of the compounds that give it the peculiar odor and flavor found in fruit that has not been held in storage at low temperatures. In the case of Bartlett pears, however, it has been found that fruit may be held in storage for periods up to two to three months and then taken out while still hard and green, provided it has been held in temperatures of 28° to 30° F. Such fruit should be ripened at a temperature of 60° to 70° F., and when removed from storage it will develop much of the aroma and flavor found in pears that have ripened in normal temperatures. Invariably it has been found that pears handled in this way, by storing at the minimum temperature until the fruit is to be used and then removing from storage entirely and ripening it at temperatures of 60° to 70° F., have given a product of higher dessert quality than that obtained by any other storage method. This method of handling is to be recommended, regardless of whether the fruit is intended for canning or for a late fresh-fruit market following removal from storage.

There has been some criticism among cannery men of holding pears at so low a temperature. It has even been said that such a procedure will cause the pears to discolor in the can. In order to determine whether or not a season at low temperature injures the fruit for canning, a quantity of pears from two different orchards was removed from storage on December 29, 1920, and was canned on January 4, 1921, almost five months after picking. This fruit made a canned product of very good quality and of splendid appearance, though there was considerable waste in preparing the pears for canning after so long a season in storage. This practice is not to be recommended, nor is it desirable from the canners' viewpoint that pears for the cannery be held more than two months in storage. The fact, however, that this fruit after so long a storage season still made an excellent canned product entirely refutes the theory that cold-storage pears, particularly if held at low temperatures during storage, make a poor quality of canned fruit.

Another important matter to the canner is the fact that pears from the districts producing fruit of poor keeping quality, such as those along the California coast, can be handled safely through cold storage. During the summer of 1920 a large quantity of pears from Santa Cruz County, Calif., supposed to be among the poorest keeping Bartletts in the State, was put in storage under the observation of the writer. This fruit was held at 30° to 31° F. for more than a

month. Upon removal from cold storage the fruit ripened normally and made a canned product of as high a quality as though it had not been placed in storage.

PEAR SCALD.

During recent years, as Bartlett pears have been held in cold storage in constantly increasing quantities, fruit has frequently come out of storage in a blackened condition. The skin is black or brown and tends to slough off very readily. The injury usually does not penetrate the tissues very deeply, but when much of the surface of the fruit is affected it renders the pear practically worthless.

Many of the men who have put fruit in cold storage have attributed this trouble to freezing in the storage rooms. This is not the case, however, for fruit that has been held at temperatures never below 35° F. has been found badly scalded upon removal from storage. It is apparently a trouble of pears in cold storage closely analogous to the storage scald of apples.

During two years of investigational work on pear storage the writer found that this trouble developed several times when fruit was removed from storage. In pears from the same trees and held under exactly similar conditions in the storage rooms, it has invariably been the early-picked fruit that scalded upon removal from storage. During the summer of 1920, Bartletts were picked from the same trees in a typical orchard in Sacramento, Calif., on June 30, July 9, 14, 24, August 3 and 13. Part of each lot of this fruit was held at 35° and part of it at 30° F. On September 24 the fruit was removed from the room having a temperature of 35° F. and held at ordinary room temperature. At that time it was yellow ripe, though still firm. The first three lots picked, from June 30 to July 13, showed practically 100 per cent scald. Lot No. 4, picked July 23, showed approximately 50 per cent scald, while lot No. 5, picked 10 days later, was almost entirely free from it. No scald showed in lot No. 6, picked on August 13. Fruit from Santa Clara, Calif., showed practically the same condition. Apparently, early-picked fruit is far more susceptible to scald than that picked late. It is particularly necessary, therefore, that fruit be well matured on the tree before picking if it is intended for cold storage.

In all of the tests so far conducted there has been less scald in fruit held at 28° to 30° F. than in that held at higher temperatures. It seems probable that this is because the fruit has been removed from storage at the lower temperature when in a hard, green condition. Scald appears to develop mainly on fruit that is removed from cold storage in a yellow-ripe condition. The late picking of fruit intended for cold storage, followed by its prompt removal to the cold-storage rooms, appears to be the best insurance against scald. Such fruit can be removed after a reasonable season in cold storage while

still firm and green tinted. Not only will this treatment give the greatest security from scald, but it will also give the highest quality product when it becomes soft ripe.

SUMMARY.

For two years chemical and physiological studies of the ripening and storage of Bartlett pears have been carried on.

The time of picking and method of handling pears vary widely in accordance with the manner in which the fruit is to be consumed.

For fresh shipment the fruit will not shrivel if picked after the lenticels are thoroughly corked over. A much superior product will be secured, however, if the initial picking is delayed until at least two weeks later than this time.

Early-picked pears after removal from the tree will remain in a hard, green condition for a much longer period than late-picked fruit from the same tree if held under normal temperature or iced-car temperature conditions.

Early-picked pears, however, after they once become soft and ripe break down and decay very quickly. Late-picked pears after softening remain in prime condition for eating for a much longer period.

There is a wide variation in the length of time the fruit from different districts will hold up following its removal from the tree. In general, the districts with relatively high temperatures and low humidity during the growing season produce Bartlett pears with the best carrying and keeping qualities.

Precooling pears before shipment is to be recommended in districts where the fruit has poor carrying qualities, provided the refrigeration capacity is sufficient to cool the fruit to 30° F. within 24 to 48 hours following its removal from the tree.

If the highest quality is to be secured pears for canning should not be removed from the tree until they show a pronounced yellow ground color beneath the green.

Bartlett pears can be held successfully in cold storage for two to three months and, if necessary, even five months, if proper methods are employed.

If fruit is to be held in cold storage, it should be allowed to come to the stage recommended for cannery picking before removing it from the tree. Early-picked fruit has a marked tendency to scald in cold storage.

Fruit should be removed to the cold-storage rooms immediately after picking and cooled quickly.

Fruit should be held at 28° to 30° F. until desired for use; then removed and allowed to ripen at 60° to 70°. This will give the highest quality for storage pears.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1073

Contribution from the Bureau of Chemistry
W. G. CAMPBELL, Acting Chief



Washington, D. C.

May 12, 1922

SOME CHANGES IN THE COMPOSITION OF CALIFORNIA AVOCADOS DURING GROWTH.

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THE CALIFORNIA AVOCADO INDUSTRY.

Avocado growing is still one of the infant industries of California. Although many single trees or small groups of trees have been in existence for some time, real attempts at commercial production extend back for little more than 10 years. About 45,000 trees are now registered, but the greater part of these are not in bearing and many more are dooryard trees not intended for commercial purposes. Large commercial plantings are rare and the industry will not reach its maximum for years to come. All of the different varieties now being planted are more or less in the experimental stage, for no large planting is old enough yet to tell what the trees will do at an advanced age under orchard conditions.

It would be difficult to list all the varieties of the avocado in California, for new types of trees are being continually raised from seed and the first fruits of several such trees are exhibited at practically all of the meetings of the California Avocado Association. The fruit of most of these trees, however, is too poor to be of use, so

¹ The writers are indebted to the California Avocado Association, a cooperative body of avocado growers, and to many individual growers for information and material of great assistance in this investigation.

that the trees are budded over to more promising varieties. At the 1920 spring meeting of the California Avocado Association more than 60 varieties of avocados were on exhibition. In a wise attempt to restrain the commercial plantings of new varieties or strains which have not been thoroughly tested, the association maintains a list of those recommended for commercial use. The varieties now listed are Dickinson, Fuerte, Puebla, Sharpless, and Spinks. Blakeman, Lyon, and Taft, listed in 1919, have been dropped. Descriptions of these varieties can be found in the annual report of the California Avocado Association for 1917 and in the Manual of Tropical and Subtropical Fruits, by Wilson Popenoe.

PURPOSE OF INVESTIGATION.

When it is desirable to harvest fruits or vegetables before they mature, the problem of determining the time of their optimum condition is seldom an easy one. It is particularly difficult in the case of fruits that are raised at a great distance from their markets, in which class belong practically all Pacific coast fruits. Much difficulty has been experienced in trying to place these fruits in eastern markets in a state satisfactory to the consumer, the tendency being to harvest the fruit before it is ready, which results in putting a poor and flavorless product in the hands of the consumer.

While it is true that the avocado has not yet reached the stage of development where it is being shipped to eastern markets in commercial quantities, that time is fast approaching, and even now, under the commercial methods of marketing it in California, knowledge of its composition at maturity is imperative. Avocados are harvested while hard and kept in storage at hotels, clubs, or markets until they have softened. If picked too early the fruit has a tendency to shrivel and become "rubbery," is watery, and lacks the characteristic flavor of well-matured fruit. Its maturity problem thus assumes special importance. Furthermore, this fruit is now in the first period of its development, as far as the American market is concerned. False impressions of its quality created at this time may greatly injure its future. Already some adverse criticism of the avocado, usually traceable to those who have bought immature fruits, is encountered.

The composition of fruit of all of the varieties now grown and of that from seedling trees brought into bearing each year, therefore, is a matter of no little interest to the avocado grower. The work here reported was undertaken for the purpose of throwing some light upon the problems just enumerated.

INVESTIGATIONAL WORK.

METHODS OF SAMPLING.

It has been somewhat difficult to get satisfactory trees from which to obtain samples. Orchards are still too few to afford much choice. For satisfactory data upon which to base opinions of either maturity or average composition, samples of each variety should be secured from each of several districts throughout the State.

Ideal conditions can be secured only where each variety is found growing in the same orchard, thus being exposed to the same climatic conditions and receiving identical cultivation. As some growers neither cultivate nor fertilize their trees, while others do both, it is well within the realm of possibility that the same variety of fruit grown under such varying conditions will differ markedly in composition and maturity. While conditions at the time this work was undertaken were far from ideal, the knowledge gained by any experiment goes far in guiding the industry along the right paths.

A single tree of each of the eight varieties recommended by the California Avocado Association in 1919² was selected, in a location where orchard conditions existed, without regard to climatic conditions. Each location was in a district where the avocado is commercially grown.

The trees were located as follows: The Blakeman at Altadena, the Dickinson at Chula Vista, the Fuerte at Yorba Linda, the Lyon at Whittier, the Puebla at San Fernando, the Sharpless at Tustin, the Spinks at Duarte, and the Taft at Yorba Linda. This list shows a wide distribution of locations, each growing district of California being represented with the exception of Ventura and Santa Barbara Counties.

All of the fruit on the trees, which were young, strong growing specimens, bearing from 25 to 75 fruits, was reserved for samples. Although most of the locations were in secluded areas, a great deal of the fruit was stolen. Loss in one location was caused by wind storms.

Depending on the number of fruits on the tree, samples consisting of from one to six fruits were sent to the laboratory for analysis at monthly intervals. When possible the samples were divided at the laboratory into equal subdivisions, one of which was analyzed at once, the other being wrapped in paper and permitted to soften at room temperature before analysis. Whenever it was necessary to store samples after they were ready for analysis, they were held at a temperature of from 35° to 45° F. The samples analyzed at once are here designated "fresh samples," the others, "storage samples."

² Three of these varieties have since been taken from the list because of alleged faults in the trees or fruits. These faults, however, had no bearing on the composition of the fruit.

METHODS OF ANALYSIS.

The methods of analysis of the Association of Official Agricultural Chemists were used.

Specific gravity of the fruit was determined by weighing it in air and under water. Each fruit was then cut in half, lengthwise, the seed removed, and the pulp separated from the skin by means of a spoon. Often it was necessary to remove the skin of the fresh immature samples by paring. In such cases the separations could not always be accurately made, a fact which must be taken into

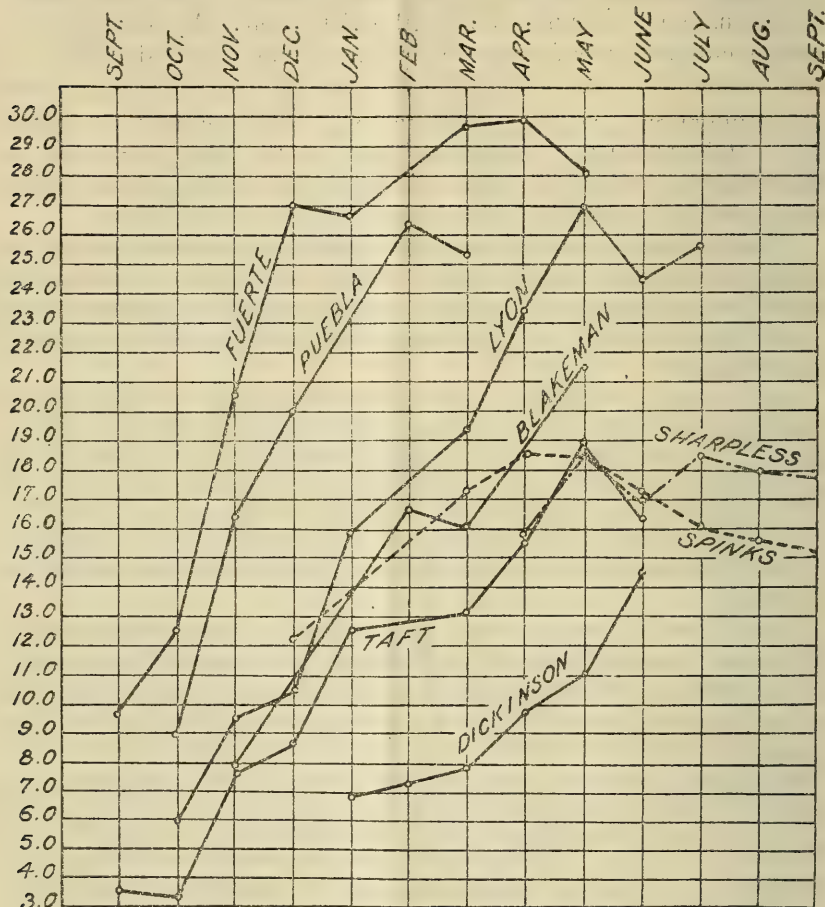


FIGURE 1.—Monthly increase in fat content of the edible portion of avocados.

consideration in interpreting the results. The seed, skin, and pulp were weighed and the percentage of each was determined.

Moisture was determined by drying to constant weight in vacuo at 70° C.

Ash was determined by thoroughly charring the sample at low heat, extracting the char with hot water, and ashing the residue at red heat. Next the water-soluble ash was added. The whole was then evaporated to dryness and heated to very low redness.

Fat was extracted from the moisture-free samples with anhydrous ether in a Soxhlet apparatus.

Sugar was determined after inversion in the cold, by the usual reduction methods, the cuprous oxid being determined by the optional official method, using ferrous sulphate and permanganate solution.

Nitrogen was determined by the Gunning method, the result obtained being multiplied by 6.25 for protein.

Crude fiber was determined by the usual method.

RESULTS OF INVESTIGATION.

The results of this investigation are given in Tables 1 to 6. Table 1 shows the rank of each variety in the matter of weight, percentage of edible portion, seed, and skin, and the percentage of protein, fat, and crude fiber in the edible portion. The data obtained from the analyses of the fruit from the selected trees are presented in Table 2, and, in order to facilitate comparisons, the same data, calculated to a water-free basis, are given in Table 3. Table 4 shows the number of days elapsing between the time the fruits were picked and the time they became soft enough to eat. Table 5 gives the results obtained from the analyses of miscellaneous samples of avocados grown in California. Table 6 gives the results obtained from the analyses of samples of fruit of the varieties introduced from Guatemala and South America by the Office of Seed and Plant Introduction, Bureau of Plant Industry, United States Department of Agriculture. Figure 1 shows the increase in the fat content of the edible portion of the standard varieties of avocados during growth.

TABLE 1.—Comparison of varieties of the avocado.

Rank.	Weight.		Seed.		Skin.	
	Variety.	Ounces.	Variety.	Per cent.	Variety.	Per cent.
1	Sharpless.....	23.4	Fuerte.....	8.5	Puebla.....	5.5
2	Spinks.....	19.3	Sharpless.....	8.6	Fuerte.....	5.6
3	Blakeman.....	18.2	Dickinson.....	9.5	Blakeman.....	6.7
4	Lyon.....	16.7	Lyon.....	9.7	Spinks.....	7.0
5	Taft.....	15.3	Taft.....	11.8	Sharpless.....	7.5
6	Fuerte.....	14.7	Blakeman.....	14.1	Taft.....	8.6
7	Dickinson.....	13.4	Spinks.....	17.7	Lyon.....	9.5
8	Puebla.....	8.3	Puebla.....	19.4	Dickinson.....	18.9

Rank.	Edible portion.		Protein in edible portion.		Fat in edible portion.		Crude fiber in edible portion.	
	Variety.	Per cent.	Variety.	Per cent.	Variety.	Per cent.	Variety.	Per cent.
1	Fuerte.....	85.0	Lyon.....	4.37	Fuerte.....	29.93	Taft.....	0.73
2	Sharpless.....	84.0	Spinks.....	2.70	Lyon.....	26.89	Sharpless.....	1.09
3	Lyon.....	78.9	Fuerte.....	2.32	Puebla.....	26.45	Spinks.....	1.09
4	Blakeman.....	76.4	Puebla.....	2.30	Blakeman.....	21.55	Puebla.....	1.12
5	Puebla.....	74.0	Blakeman.....	2.25	Taft.....	18.39	Lyon.....	1.15
6	Spinks.....	73.0	Sharpless.....	1.92	Spinks.....	18.53	Dickinson.....	1.19
7	Taft.....	72.0	Dickinson.....	1.66	Sharpless.....	18.41	Blakeman.....	1.24
8	Dickinson.....	68.5	Taft.....	1.36	Dickinson.....	14.45	Fuerte.....	1.35

TABLE 2.—Composition of avocados at different stages of maturity.

BLAKEMAN (ALTADENA).

Sample No.	Month picked.	Condition.	Average weight.	Specific gravity.	Edible portion.	Skin.	Seed.	Edible portion.					
								Moisture.	Ash.	Protein.	Fat.	Total sugars.	Crude fiber.
			Ozs.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
42	Nov...	Storage...	10.9	0.9638	73.1	12.6	14.1	84.37	0.87	1.11	7.83	1.76	1.24
69	Feb...	Fresh...	14.3	.9915	76.8	12.9	9.9	75.67	1.38	1.01	13.93	1.69	-----
70	Feb...	Storage...	13.1	.9868	74.4	10.7	14.7	75.77	1.50	1.22	16.56	.82	1.25
81	Mar...	do.....	16.5	1.0085	74.6	9.4	15.7	76.16	1.22	1.03	16.04	.70	1.25
107	May...	do.....	18.2	1.0188	76.4	6.7	16.9	69.14	1.61	2.25	21.55	.49	1.53

DICKINSON (CHULA VISTA).

59	Jan...	Fresh....	11.6	1.0173	65.3	22.8	11.2	84.84	0.90	0.79	4.17	3.50	-----
60	Jan...	Storage...	10.6	.9428	68.4	21.9	9.5	86.47	1.20	1.01	6.84	.37	-----
71	Feb...	Fresh....	11.2	1.0159	65.0	24.5	10.2	84.23	.94	.79	5.87	2.80	-----
72	Feb...	Storage...	9.7	.9753	67.6	19.7	13.0	86.10	1.02	.94	7.20	.55	1.34
83	Mar...	Fresh....	11.4	1.0160	62.0	25.1	12.3	83.95	1.03	.94	6.15	2.52	-----
84	Mar...	Storage...	10.2	.9540	66.7	20.6	12.7	85.40	1.19	1.31	7.80	.58	1.30
95	Apr...	Fresh....	11.6	1.0063	62.0	23.3	14.3	84.56	1.23	1.37	7.63	.67	-----
96	Apr...	Storage...	10.5	.9650	65.8	20.8	13.1	84.71	1.12	1.31	9.68	.36	1.19
100	May...	do.....	10.9	1.0031	68.3	18.2	13.3	82.74	1.32	1.66	9.84	.41	1.30
110	May...	do.....	13.4	.9858	68.5	18.9	12.7	81.03	1.28	1.40	10.96	.46	1.26
120	June...	Fresh....	16.0	.9892	70.2	18.8	10.9	75.41	1.41	1.90	14.06	1.16	-----
121	June...	Storage...	11.2	.9770	60.1	21.4	18.5	75.82	1.56	1.66	14.45	.57	1.68

FUERTE (YORBA LINDA).

23	Sept...	Fresh....	8.9	0.9958	73.4	11.0	14.6	81.69	0.72	1.50	6.97	3.06	1.27
24	Sept...	Storage...	5.7	.9969	76.9	9.5	13.0	82.33	.80	1.66	9.61	.69	1.48
31	Oct...	Fresh....	11.5	.9921	77.6	8.3	13.5	78.35	.76	1.44	11.32	2.12	1.35
32	Oct...	Storage...	10.1	1.0099	77.8	6.2	15.4	78.97	.91	1.75	12.46	1.02	1.50
46	Nov...	Fresh....	11.2	.9864	78.0	7.7	13.8	72.72	1.02	1.55	17.61	1.08	1.32
47	Nov...	Storage...	10.2	1.0075	76.4	8.4	16.7	70.93	1.24	1.88	20.57	.71	1.62
52	Dec...	Fresh....	12.2	.9764	77.1	6.3	14.1	67.42	1.17	1.71	23.99	.58	1.47
53	Dec...	Storage...	10.0	.9810	80.5	6.8	12.5	64.18	1.69	1.99	26.99	.57	1.64
62	Jan...	Fresh....	13.9	.9728	76.5	7.7	15.2	65.99	1.24	1.49	25.12	.38	1.33
63	Jan...	Storage...	12.6	.9967	79.4	6.3	13.9	65.31	1.25	1.49	26.62	.29	1.44
76	Mar...	Fresh....	16.7	.9616	79.9	7.7	11.9	63.93	1.34	1.73	26.13	.17	1.08
77	Mar...	Storage...	14.7	.9861	81.6	5.6	12.7	62.08	1.43	1.68	29.74	.39	1.36
88	Apr...	Fresh....	13.9	.9596	79.2	9.1	11.2	63.46	1.40	1.88	28.19	.11	1.25
89	Apr...	Storage...	13.1	.9626	82.6	7.5	9.7	62.07	1.42	2.10	29.93	.31	1.42
97	May...	Fresh....	11.4	.9688	78.9	10.9	9.7	61.08	1.33	2.32	30.15	.13	1.24
98	May...	Storage...	11.4	.9616	85.0	6.0	8.5	63.94	1.41	2.32	28.06	.28	1.35

LYON (WHITTIER).

27	Oct...	Fresh....	5.5	0.9954	61.9	19.1	18.4	85.87	0.61	1.71	4.26	2.59	-----
28	Oct...	Storage...	4.8	.9790	65.5	15.6	18.6	85.45	.87	2.10	5.90	1.56	1.15
38	Nov...	Fresh....	11.2	.9968	65.4	16.1	17.5	82.48	.73	1.36	6.55	3.31	-----
39	Nov...	Storage...	9.1	.9144	66.7	13.8	19.4	83.13	.81	1.71	9.52	1.81	1.20
54	Dec...	Fresh....	12.4	.9902	66.6	15.8	17.1	81.49	.68	1.27	7.63	3.28	-----
55	Dec...	Storage...	9.8	.9292	69.0	12.9	18.0	80.59	.93	1.49	10.42	2.24	1.16
65	Jan...	Fresh....	12.5	1.0052	68.0	18.2	13.5	73.20	.96	1.93	14.01	2.92	-----
66	Jan...	Storage...	10.3	.9317	63.6	13.0	23.2	74.83	1.06	2.25	15.76	1.51	1.35
79	Mar...	Fresh....	14.3	.9990	68.6	15.3	15.8	69.85	1.09	2.34	16.66	1.67	-----
80	Mar...	Storage...	13.4	.9892	68.6	11.7	19.4	70.66	1.17	2.45	19.29	1.90	1.19
90	Apr...	Fresh....	16.5	.9833	70.9	14.8	14.1	66.79	1.19	2.60	21.34	1.29	-----
91	Apr...	Storage...	13.2	.9798	70.5	10.8	18.6	66.13	1.24	3.02	23.41	1.65	1.25
105	May...	Fresh....	14.8	.9849	72.5	14.6	12.4	62.95	1.19	3.41	25.07	.80	-----
106	May...	Storage...	10.6	.9719	78.9	11.4	9.7	61.56	1.43	4.37	26.89	.94	1.29
116	June...	Fresh....	15.9	.9827	77.1	11.5	11.0	64.44	1.33	2.66	22.91	1.07	-----
117	June...	Storage...	15.3	1.0051	76.9	9.5	13.0	64.58	1.29	3.28	24.43	.37	1.22
122	July...	do.....	16.7	.9656	77.8	11.1	11.0	68.52	1.17	3.02	25.57	.53	1.15

TABLE 2.—Composition of avocados at different stages of maturity—Continued.

PUEBLA (SAN FERNANDO).

Sample No.	Month picked.	Condition.	Average weight.	Specific gravity.	Edible portion.	Skin.	Seed.	Edible portion.					
								Moisture.	Ash.	Protein.	Fat.	Total sugars.	Crude fiber.
			Ozs.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
36	Oct...	Fresh....	6.9	1.0107	64.9	10.3	24.4	82.88	0.83	1.77	6.72	2.31	.....
37	Oct...	Storage..	5.7	1.0324	67.5	6.1	25.6	80.12	1.10	2.30	8.87	2.58	1.35
40	Nov...	Fresh....	7.2	1.0147	67.7	8.4	23.6	76.29	1.09	1.62	13.12	1.64	.....
41	Nov...	Storage..	6.9	1.0324	67.6	5.8	26.4	73.49	1.34	2.08	16.36	1.45	1.43
48	Dec...	Fresh....	7.6	1.0022	72.7	7.9	19.0	73.50	1.17	1.62	15.59	1.74	.....
49	Dec...	Storage..	6.6	1.0282	71.4	5.5	22.8	70.01	1.60	2.02	19.99	1.47	1.40
68	Feb...	do.....	6.5	1.0225	68.1	8.1	23.3	63.59	1.72	2.19	26.45	.88	1.42
82	Mar...	do.....	8.3	1.0232	74.0	6.2	19.4	64.89	1.77	2.27	25.33	.75	1.12

SHARPLESS (TUSTIN).

92	Apr...	Fresh....	18.5	0.9906	75.2	13.7	10.4	77.11	1.13	1.07	14.73	1.54	.....
93	Apr...	Storage..	18.2	.9312	77.9	10.6	11.7	77.34	1.23	1.37	15.68	.68	1.13
101	May...	Fresh....	16.4	.9884	72.1	15.1	12.5	76.11	1.17	1.13	16.05	.88	.....
102	May...	Storage..	11.7	.9501	75.1	12.8	12.0	74.57	1.38	1.27	18.41	.60	1.14
112	June...	Fresh....	18.8	.9811	75.3	13.2	11.2	76.99	1.29	1.33	15.79	.41	.....
113	June...	Storage..	23.0	.9255	81.9	7.9	10.2	75.83	1.46	1.31	16.91	.40	1.12
124	July...	do.....	22.4	.9781	80.0	9.2	10.6	74.65	1.50	1.44	18.39	.27	1.09
127	Aug...	Fresh....	26.6	.9812	78.2	11.7	10.0	73.33	1.42	1.78	18.47	.34	.....
128	Aug...	Storage..	23.4	.9908	84.0	7.5	8.6	73.97	1.58	1.92	17.88	.25	1.12
130	Sept...	do.....	22.9	.9762	82.8	7.6	9.2	74.94	1.51	1.36	17.71	.36	1.20

SPINKS (DUARTE).

56	Dec...	Fresh....	11.5	0.9718	60.8	12.8	25.9	78.55	1.13	1.40	11.03	2.16	.....
57	Dec...	Storage..	13.0	.9460	64.8	11.8	23.3	77.62	1.52	1.77	12.22	1.06	1.27
71	Mar...	Fresh....	15.8	.9853	64.1	12.2	23.3	76.15	1.19	1.53	14.36	1.52	.....
75	Mar...	Storage..	12.6	.9350	69.8	10.6	19.1	73.04	1.42	1.84	17.23	.93	1.28
85	Apr...	Fresh....	17.5	.9527	65.2	13.5	20.7	72.56	1.43	2.35	18.13	.58	.....
86	Apr...	Storage..	18.8	1.0001	69.5	8.5	21.8	72.66	1.44	2.32	18.53	.59	1.09
108	May...	Fresh....	21.0	.9450	68.5	9.4	21.7	73.74	1.40	2.40	16.96	.17	.....
109	May...	Storage..	19.3	.9477	73.0	7.0	19.2	72.85	1.54	2.36	18.37	.53	1.11
118	June...	Fresh....	16.9	.9403	69.1	11.2	19.3	74.15	1.24	1.79	17.03	.42	.....
119	June...	Storage..	13.1	1.0038	71.0	11.2	17.7	73.47	1.42	1.92	17.21	.62	1.37
125	July...	do.....	17.5	1.0147	64.0	7.0	29.0	75.66	1.42	1.66	16.04	.40	.....
126	Aug...	do.....	15.3	1.0152	69.5	8.9	21.4	75.27	1.53	2.70	15.54	.62	1.20
129	Sept...	do.....	18.8	.9830	71.8	8.1	20.2	75.66	1.60	2.62	15.14	.40	1.09

TAFT (YORBA LINDA).

25	Sept...	Fresh....	4.8	0.9870	64.7	10.7	23.9	87.97	0.58	1.23	3.20	3.60	.....
26	Sept...	Storage..	3.8	.9869	71.5	8.6	19.8	88.67	.79	1.36	3.51	1.58	1.00
34	Oct...	Fresh....	7.4	1.0044	71.3	16.5	11.4	87.57	.59	.96	2.39	3.50	.....
35	Oct...	Storage..	4.9	.9460	71.8	16.4	11.8	88.67	.67	1.16	3.54	2.04	.73
44	Nov...	Fresh....	9.8	1.0031	70.6	17.0	11.6	84.34	.72	.66	6.45	2.93	.....
45	Nov...	Storage..	8.5	.9443	67.3	16.7	15.8	84.40	.85	.83	7.56	1.71	.99
50	Dec...	Fresh....	7.9	1.0020	68.9	17.0	13.3	83.58	.78	.52	6.88	2.51	.....
51	Dec...	Storage..	8.3	.9749	70.8	13.8	15.3	83.86	1.13	.79	8.60	1.28	.93
61	Jan...	do.....	8.2	.9324	70.1	16.2	13.7	80.04	1.24	1.03	12.46	.71	.97
78	Mar...	do.....	14.4	.9927	72.0	11.7	16.3	78.87	1.11	.79	13.12	.68	.91
87	Apr...	do.....	14.2	.9833	70.1	12.2	17.2	76.52	1.35	1.40	15.51	.71	.95
103	May...	Fresh....	15.8	.9811	69.8	15.1	14.6	72.01	1.60	1.53	19.48	.71	.....
104	May...	Storage..	15.3	1.0025	71.6	10.8	17.4	73.75	1.45	1.31	18.89	.58	1.03
114	June...	Fresh....	16.4	.9981	65.4	14.5	18.9	71.56	1.47	1.22	20.27	.44	.....
115	June...	Storage..	10.8	1.0141	70.4	11.1	18.7	76.19	1.51	1.31	16.34	.68	.97

TABLE 3.—Composition of avocados at different stages of maturity (calculated to water-free basis).

BLAKEMAN (ALTADENA).

Sample No.	Month picked.	Condition.	Ash.	Protein.	Fat.	Total sugars.	Crude fiber.	Undetermined.
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
42	Nov.	Storage.	5.57	7.10	50.09	11.26	7.89	18.04
69	Feb.	Fresh.	5.67	4.15	57.25	6.95		
70	Feb.	Storage.	6.19	5.03	68.35	3.38	5.15	11.89
81	Mar.	do.	5.12	4.32	67.28	2.94	5.24	15.10
107	May.	do.	5.22	7.29	69.83	1.59	4.96	11.11

DICKINSON (CHULA VISTA).

59	Jan.	Fresh.	5.93	5.21	27.49	23.07		
60	Jan.	Storage.	8.87	7.46	50.55	2.73		
71	Feb.	Fresh.	5.96	5.01	37.24	17.75		
72	Feb.	Storage.	7.37	6.76	51.79	3.96	9.64	20.50
83	Mar.	Fresh.	6.42	5.86	38.33	15.70		
84	Mar.	Storage.	8.15	8.97	53.42	3.97	8.90	16.58
95	Apr.	Fresh.	7.97	8.87	49.43	4.34		
96	Apr.	Storage.	7.32	8.57	63.33	2.35	7.78	10.66
100	May.	do.	7.65	9.62	57.00	2.38	7.53	15.82
110	May.	do.	6.75	7.38	57.77	2.42	6.64	19.03
120	June.	Fresh.	5.73	7.73	57.18	4.72		
121	June.	Storage.	6.45	6.86	59.76	2.36	6.95	17.62

FUERTE (YORBA LINDA).

23	Sept.	Fresh.	3.93	8.19	38.06	16.71	6.94	26.16
24	Sept.	Storage.	4.53	9.39	54.38	3.90	8.38	19.41
31	Oct.	Fresh.	3.51	6.65	52.28	9.79	6.24	21.52
32	Oct.	Storage.	4.33	8.32	59.25	4.85	7.13	16.12
46	Nov.	Fresh.	3.74	5.68	64.55	3.96	4.84	17.23
47	Nov.	Storage.	4.27	6.47	70.76	2.44	5.57	10.49
52	Dec.	Fresh.	3.59	5.25	73.64	1.78	4.51	11.23
53	Dec.	Storage.	4.72	5.56	75.35	1.59	4.58	8.21
62	Jan.	Fresh.	3.65	4.38	73.86	1.12	3.91	13.08
63	Jan.	Storage.	3.60	4.29	76.73	.84	4.15	10.38
76	Mar.	Fresh.	3.72	4.80	72.45	.47	2.99	15.58
77	Mar.	Storage.	3.77	4.43	78.43	1.03	3.59	8.76
88	Apr.	Fresh.	3.83	5.15	77.15	.80	3.42	10.15
89	Apr.	Storage.	3.74	5.54	78.91	.82	3.74	7.25
97	May.	Fresh.	3.42	5.96	77.47	.33	3.19	9.64
98	May.	Storage.	3.91	6.43	77.82	.78	3.74	7.32

LYON (WHITTIER).

27	Oct.	Fresh.	4.32	12.10	30.15	18.33		
28	Oct.	Storage.	5.98	14.43	40.55	10.72	7.90	20.41
38	Nov.	Fresh.	4.17	7.76	37.38	13.89		
39	Nov.	Storage.	4.80	10.14	56.43	10.73	7.11	10.79
54	Dec.	Fresh.	3.67	6.86	41.24	17.72		
55	Dec.	Storage.	4.79	7.68	53.69	11.54	5.98	16.33
65	Jan.	Fresh.	3.58	7.30	52.27	10.89		
66	Jan.	Storage.	4.21	8.94	62.61	6.00	5.36	12.87
79	Mar.	Fresh.	3.62	7.76	55.26	5.54		
80	Mar.	Storage.	3.99	8.35	65.75	6.48	4.06	11.38
90	Apr.	Fresh.	3.58	7.33	64.26	3.88		
91	Apr.	Storage.	3.66	8.92	69.12	4.87	3.69	9.74
105	May.	Fresh.	3.21	9.20	67.67	2.16		
106	May.	Storage.	3.72	11.37	69.96	2.45	3.36	9.16
116	June.	Fresh.	3.74	7.48	64.43	3.01		
117	June.	Storage.	3.64	9.26	68.97	1.04	3.44	13.64
122	July.	do.	3.72	9.59	81.22	1.68	3.65	.13

PUEBLA (SAN FERNANDO).

36	Oct.	Fresh.	4.85	10.34	39.25	13.49		
37	Oct.	Storage.	5.53	11.57	44.62	12.98	6.79	18.51
40	Nov.	Fresh.	4.60	6.83	55.33	6.92		
41	Nov.	Storage.	5.05	7.85	61.71	5.47	5.39	14.52
48	Dec.	Fresh.	4.41	6.11	58.83	6.57		
49	Dec.	Storage.	5.33	6.74	66.65	4.90	4.67	11.70
68	Feb.	do.	4.72	6.02	72.65	2.42	3.90	10.30
82	Mar.	do.	5.04	6.47	72.14	2.14	3.19	11.02

TABLE 3.—Composition of avocados at different stages of maturity (calculated to water-free basis)—Continued.

SHARPLESS (TUSTIN).

Sam- ple No.	Month picked.	Condition.	Ash.	Protein.	Fat.	Total sugars.	Crude fiber.	Undeter- mined.
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
92	Apr.	Fresh	4.94	4.67	64.35	6.73		
93	Apr.	Storage	5.43	6.05	69.19	2.56	4.99	11.77
101	May	Fresh	4.90	4.73	67.18	3.68		
102	May	Storage	5.43	4.99	72.40	2.36	4.48	10.34
112	June	Fresh	5.61	5.78	68.62	1.78		
113	June	Storage	6.04	5.42	69.97	1.65	4.63	12.29
124	July	do.	5.92	5.68	72.55	1.07	4.30	10.49
127	Aug.	Fresh	5.32	6.17	69.25	1.27		
128	Aug.	Storage	6.07	7.38	68.69	.96	4.30	12.60
130	Sept.	do.	6.02	5.43	70.67	1.44	4.79	11.65

SPINKS (DUARTE).

56	Dec.	Fresh	5.27	6.53	51.42	10.07		
57	Dec.	Storage	6.79	7.91	54.60	4.74	5.67	20.28
74	Mar.	Fresh	4.99	6.41	60.21	6.37		
75	Mar.	Storage	5.27	6.82	63.91	3.45	4.75	15.80
85	Apr.	Fresh	5.21	8.60	66.07	2.11		
86	Apr.	Storage	5.27	8.49	67.78	2.16	3.99	12.33
108	May	Fresh	5.33	9.14	64.59	.65		
109	May	Storage	5.67	8.69	67.66	1.95	4.09	11.93
118	June	Fresh	4.80	6.92	65.88	1.62		
119	June	Storage	5.35	7.24	64.87	2.34	5.16	15.04
125	July	do.	5.83	6.82	65.90	1.64		
126	Aug.	do.	6.19	10.92	62.84	2.51	4.85	12.70
129	Sept.	do.	6.57	10.76	62.20	1.64	4.48	14.34

TAFT (YORBA LINDA).

25	Sept.	Fresh	4.82	10.22	18.29	29.92		
26	Sept.	Storage	6.97	12.00	30.98	13.95	8.82	27.27
34	Oct.	Fresh	4.75	7.72	19.23	28.16		
35	Oct.	Storage	5.91	10.24	24.98	18.00	6.44	29.92
44	Nov.	Fresh	4.69	4.21	41.17	18.71		
45	Nov.	Storage	5.47	5.34	48.65	11.00	6.37	23.16
50	Dec.	Fresh	4.75	3.17	41.90	15.28		
51	Dec.	Storage	7.00	4.89	53.28	7.93	5.76	21.13
61	Jan.	do.	6.21	5.16	62.42	3.56	4.86	17.79
78	Mar.	do.	5.25	3.74	62.09	3.22	4.31	21.39
87	Apr.	do.	5.75	5.96	66.10	3.02	4.05	15.16
103	May	Fresh	5.72	5.47	69.59	2.54		
104	May	Storage	5.52	4.99	71.97	2.21	3.92	11.39
114	June	Fresh	5.17	4.29	71.27	1.55		
115	June	Storage	6.34	5.50	68.63	2.86	4.07	12.60

TABLE 4.—Number of days required for softening avocados.

Variety.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
Spinks					9		7	6	6	2	2	6	6
Fuerte	13	11		12	16	6	7	5	6				
Taft	14	12		13	16	19	6	5	7	5			
Puebla		12		14	13	12	10						
Lyon		12-15	22		17	19	8	5	6	4			
Sharpless								10	7	5	2	6	10
Dickinson					22	17	20	9	9-10	3			
Blakeman				14		9	6		9				

TABLE 5.—Composition of miscellaneous samples of California avocados.

Sample No.	Variety.	Location.	Date.		Outside color.		Average weight per fruit.	Seed.	Pulp.	Skin.	Edible portion.					Remarks.
			Picked.	Softened.	Fresh.	Storage.					Ash.	Protein.	Fat.	Total sugars.	Crude fiber.	
1	Fuerte.	Yorba Linda	1917. Mar. 2	1917. Mar. 20		Green.	6.3									
2	Small round.	do.	do.	Mar. 22		Green, dark spots.	5.8	15.7	74.4	9.1	1.23	1.98	23.11	.67	1.93	Mature. Do.
5	Fuerte.	do.	Mar. 17	Apr. 5		Dark green.	8.6	18.2	74.4	7.0	1.59	1.92	24.25	.80	1.47	Do.
10	do.	Altadena	July 13	July 20		Partly purple.	10.27	11.6	81.9	5.2	1.67	2.27	27.64	.27	2.14	Do.
15	do.	do.	July 15	do.		Dark green—dark purple.	7.41	10.2	80.7	7.6	1.64	2.22	28.95	.37	1.72	Slightly over-mature.
18	do.	do.	July 25	Aug. 13		Green and black.	9.91	14.9	74.9	9.3	1.71	2.22	27.63	.49	1.61	Overmature.
33	Seedless Fuerte.	Yorba Linda	1919. Oct. 16	1919. Oct. 29		Green.	.85		88.1	10.2	1.04	2.36	10.62	1.43		Immature.
64	do.	do.	1920. Jan. 30	1920. Feb. 11		do.	.88		85.32	13.9	1.37	1.71	24.92	.59		Mature.
3	Sharpless.	Santa Ana.	1917. Mar. 2	1917. Mar. 22		Blackish purple.	17.7	14.6	73.2	7.6	1.16	1.83	16.90	.74	1.37	Maturity doubtful. Do.
4	Lambert.	Hollywood.	Mar. 13	Apr. 5		Green, dark spots.	10.2	22.9	68.0	8.8	1.26	2.47	15.21	1.33	1.79	
6	Monroe.	Santa Ana.	Mar. 29	do.		do.	13.9	26.2	62.1	11.6	1.11	2.04	15.89	.90	1.63	
7	Lyon.	La Habra.	Apr. 10	do.		do.	15.2	19.3	69.0	11.4	.97	2.11	13.36	1.99	1.22	Maturity doubtful.
29	do.	Whittier.	1919. Oct. 3	1919. Oct. 18		do.	7.7	14.7	71.2	13.8	.94	2.78	6.61	1.11		Very immature.
8	Surprise.	Hollywood.	1917. Apr. 11	1917.		do.	16.7	22.2	70.1	7.7	1.15	2.38	10.07	1.50	1.29	Maturity doubtful.
9	Dickey A.	Northhoff.	May 21	June 7		Dark purple—black.	17.4	19.1	72.4	8.1	1.26	2.32	11.60	.31	1.65	

		Whittier.	1919. Oct. 3	1919. Oct. 14		Green, one- third pur- ple.	7.0	.9885	8.1	78.6	13.3	85.44	.65	1.75	6.37	1.56	1.11	Very immat- ure.
39	do.																	
11	Challenge.	Los Angeles.	1917. July 13	1917. July 31		Black.	10.9	1.0074	20.2	74.0	5.4	81.39	1.09	3.18	10.90	.62	.85	Matu rity doubtful.
12	Spinks.	Duarte.	July 17	July 23		Dark pur- ple-black.	14.4	1.0066	18.1	73.5	8.4	76.23	1.43	2.29	16.43	.41	1.38	Mature.
13	Carbon.	do.	do.	Aug. 13		Black.	12.3	1.0369	24.6	65.5	9.7	75.81	1.75	2.92	13.44	.71	2.02	Immature.
14	L. N. L.	do.	do.	July 25		Green and purple.	25.9	.9782	11.8	76.3	11.6	78.92	1.54	2.81	12.55	.41	1.66	Probably ma- ture.
181	Knight	do.	1921. June 30	Green.			16.86	.9558	17.22	70.60	12.12	77.18			14.88			Mature.
182	do.	do.	do.	do.		Green.	16.94	.9742	17.93	68.38	13.42	77.20			15.06			Do.
183	Spinks seed- ling No. 1.	do.	do.	July 9			21.49	.9845	16.25	61.39	22.04	73.74			17.46			Do.
184	do.	do.	do.	July 9		Green, one- t h i r d brown.	17.53	.9814	16.22	70.27	13.21	79.70			12.76			Do.
185	Spinks seed- ling No. 2.	do.	do.	do.			19.16	.9698	15.84	71.06	13.18	80.66			13.14			Do.
186	do.	do.	do.	July 9		Green, part brown.	18.46	.9679	14.64	74.71	10.36	80.04			14.10			Do.
187	Spinks seed- ling No. 3.	do.	do.	do.			18.49	.9733	17.27	73.34	9.20	68.25			23.31			Do.
188	do.	do.	do.	July 9		One - half green, one- half brown.	13.57	.9942	14.87	75.95	9.11	68.98			22.70			Do.
189	Alexandria seedling.	do.	do.	do.			27.67	.9466	10.72	80.53	8.89	78.06			16.68			Do.
190	do.	do.	do.	Bright green.		Green.	22.19	.9906	10.99	81.19	7.75	79.13			15.14			Do.
16	Blakeman.	Hollywood.	1917. July 24	Aug. 20		Dark green, black spots.	9.4	1.0389	16.5	76.0	7.6	74.24	1.52	3.19	15.25	.64	1.90	
17	Murietta seed- ling, Butter- cup.	do.	do.	July 31		Green.	12.3	1.0280	24.2	62.5	12.9	75.58	1.24	1.93	14.91	.27	1.45	
19	Taft.	Orange.	July 30	July 30		Dark green, b l a c k spots.	14.3		21.2	69.4	9.2	70.42	1.59	3.14	19.87	.49	1.40	Overmature.
22	Linda.	Yorba Linda	1919. Aug. 22	Aug. 22		Dark pur- ple.	27.6	.9937	15.8	72.4	11.3	78.86	1.31	1.81	13.36	.72	1.30	Mature.
38	Guatemalan seedling.	Sierra Madre	Jan. 6	Jan. 15		Brownish- purple.	15.2	.9548	19.2	65.98	14.7	65.93	1.89	1.73	24.89	1.00	1.42	Overmature.
67	Mexican No. 3.	Whittier.	1920. Jan. 30	Feb. 16		Green.	16.5	.9288	9.5	80.22	10.7	80.38	1.08	1.97	11.51	.67	1.23	Matu rity doubtful.

TABLE 5.—Composition of miscellaneous samples of California avocados—Continued.

Sample No.	Variety.	Location.	Date.		Outside color.		Average weight per fruit.	Seed.	Pulp.	Skin.	Edible portion.					Remarks.		
			Picked.	Softened.	Fresh.	Storage.					Moisture.	Ash.	Protein.	Fat.	Total sugars.		Crude fiber.	
73	Dutton seedling.	Anaheim...	1920. Feb. 21	1920. Mar. 8	.....	Purple.....	Ounces 9.2	Per cent. 1.0202	Per cent. 22.6	Per cent. 68.57	Per cent. 8.9	Per cent. 81.21	Per cent. 1.06	Per cent. 2.26	Per cent. 11.09	Per cent. 0.66	Per cent. 1.27	.....
131	Oakley No. 1.	Santa Monica.	Sept. 23	.....	Slight green, purple.	.....	19.6	.9743	17.5	72.96	9.2	70.78	1.21	3.01	16.92	.40	.....	Maturity doubtful.
132	do.....	do.....	do.....	Oct. 3	do.....	Purple.....	17.2	1.0157	17.2	76.59	6.1	69.45	1.30	3.81	19.44	.78	1.57	Do.
133	Oakley No. 2.	do.....	do.....	Oct. 3	Green.	.....	16.8	.9523	19.2	72.29	8.1	78.24	.83	1.94	12.07	2.04	.....	Do.
134	do.....	do.....	do.....	Oct. 3	do.....	Green, dark spot.	16.3	.9607	14.9	79.21	5.8	78.01	.96	2.67	13.63	.80	1.11	Do.
135	Oakley No. 3.	do.....	do.....	Oct. 8	Purple.....	Blackish purple.	15.9	.9865	10.1	83.57	6.2	71.13	1.41	3.54	18.23	.59	.....	Mature.
136	Oakley No. 4.	do.....	do.....	Oct. 4	do.....	do.....	10.4	1.0083	15.8	77.16	6.9	65.76	1.58	3.67	22.64	.50	1.54	Do.
94	Anna Campbell seedling.	Hollywood.	Apr. 18	Apr. 20	Dark purple.	Dark purple.	10.8	.9701	18.9	69.62	11.3	72.22	1.27	2.75	19.26	.85	1.01	Do.
142	Hoff seedling.	do.....	Nov. 2	Nov. 15	Olive green.	Olive green.	13.6	1.0013	17.5	76.17	6.3	71.13	1.51	2.23	18.47	.....	1.34	Do.
161	America seedling.	do.....	1921. June 21	June 22	.....	Purple.....	22.8	.9272	6.7	86.62	6.3	81.34	.....	2.20	11.34	.87	.....	Overmature.
200	Harvey Spencer seedling.	do.....	Aug. 8	Aug. 15	Black.....	Black.....	12.0	1.0089	21.7	69.25	8.8	74.01	.....	1.96	16.59	.....	.....	Mature.
160	Delicious seedling.	Pasadena.	June 10	June 22	Purple.....	Purple.....	9.1	.9728	20.6	64.84	13.3	71.69	.....	2.26	19.79	.85	.....	Do.
163	Gage seedling.	Fullerton.	June 27	July 5	Bright green.	Green, slight brown.	16.2	.9882	22.5	66.34	11.1	62.94	.....	2.98	25.23	.....	.....	Do.
202	Quaker seedling.	Whittier.	Sept. 24	Oct. 3	Green.....	Dark green.	16.5	.....	10.4	81.14	8.3	72.92	.....	1.90	19.53	.....	.....	Do.

TABLE 6.—Composition of varieties of avocado introduced by Office of Seed and Plant Introduction, Bureau of Plant Industry.

Sample No.	Variety	S. P. I. No.	Date.		Outside color.		Average weight per fruit.	Specific gravity.	Seed.	Pulp.	Skin.	Edible portion.					Remarks.
			Picked.	Softened.	Fresh.	Storage.						Ash.	Protein.	Fat.	Total sugars.	Crude fiber.	
							Ounces.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
146	Pankay	44785	1921, May 5	1921, May 9	Green.	Green.	10.73	0.9202	15.86	62.15	21.98	1.42	1.24	20.38	0.81	1.68	Mature.
147	do.	do.	do.	do.	Green.	Green.	10.93	1.0058	14.03	59.07	26.64	1.26	1.11	1.55	1.55	1.55	Do.
175	do.	do.	June 30	do.	Bright green.	Green, one-half dark	8.79	1.0152	20.16	52.50	26.85	1.44	1.34	16.35	1.44	1.44	Do.
176	do.	do.	do.	July 9	do.	do.	10.95	.9944	13.14	64.50	22.12	1.06	1.06	18.59	1.06	1.06	Do.
148	Benik	44626	May 5	May 13	Purple-green.	Purple-brown.	13.53	.9948	13.49	70.56	15.82	0.64	1.52	21.10	.80	1.17	Do.
177	do.	do.	June 30	do.	do.	do.	14.70	.9906	14.32	68.50	16.95	1.54	22.47	1.54	22.47	1.54	Do.
178	do.	do.	do.	July 8	do.	Purple.	15.50	1.0057	14.04	72.82	13.18	1.60	23.16	1.60	23.16	1.60	Do.
130	Mayapan.	44680	May 5	do.	Green—slight purple.	do.	12.12	.9980	14.47	65.12	20.26	1.30	1.40	14.46	1.44	1.44	Do.
149	do.	do.	do.	May 12	do.	Dark purple, slight green.	9.69	.9770	10.51	69.20	19.93	1.18	1.09	16.66	.40	1.49	Do.
173	do.	do.	June 30	do.	do.	Purple, green spots.	11.25	.9954	12.00	67.81	19.88	1.22	17.45	1.22	17.45	1.22	Do.
174	do.	do.	do.	July 11	do.	do.	12.77	1.0000	12.50	68.96	18.34	1.62	18.11	1.62	18.11	1.62	Do.
131	Cantal.	44783	May 5	May 28	Green.	Green.	11.77	.9773	10.58	69.75	19.22	.98	1.22	12.12	2.74	2.74	Immature.
132	do.	do.	do.	do.	do.	do.	11.82	.9175	10.10	75.14	14.76	1.26	1.75	14.34	.27	1.38	Do.
168	do.	do.	June 30	do.	do.	do.	10.47	.9704	10.39	65.25	19.42	1.31	17.82	1.31	17.82	1.31	Do.
169	do.	do.	do.	July 11	do.	do.	11.40	.9518	10.26	72.62	15.85	1.22	17.34	1.22	17.34	1.22	Do.
133	Nimlooh.	44440	May 5	do.	do.	do.	24.36	.9744	17.94	67.56	14.26	.89	.94	11.15	3.10	3.10	Immature.
134	do.	do.	do.	May 21	do.	do.	16.53	.9702	16.14	70.32	13.48	1.06	1.71	11.13	.70	1.05	Do.
164	do.	do.	June 30	do.	Bright green, dark spots.	do.	23.90	.9701	11.82	72.40	15.05	.83	.83	15.84	1.05	1.05	Mature.
165	do.	do.	do.	do.	do.	do.	20.91	.9723	15.17	71.81	12.92	1.05	13.88	1.05	13.88	1.05	Do.
136	Lamat.	43476	May 5	July 8	do.	Green.	12.28	.9823	10.23	68.20	21.06	1.15	.93	13.25	1.49	1.49	Do.
155	do.	do.	do.	May 7	do.	Green, dark spots.	11.88	.9107	14.92	67.36	17.78	1.22	1.12	12.84	.27	1.40	Do.
166	do.	do.	June 30	do.	do.	do.	10.60	.9902	8.68	71.19	19.87	1.44	18.38	1.44	18.38	1.44	Do.
167	do.	do.	do.	July 11	do.	Green.	12.30	.9538	11.27	71.39	17.26	1.27	14.02	1.27	14.02	1.27	Do.

TABLE 6.—Composition of varieties of avocado introduced by Office of Seed and Plant Introduction, Bureau of Plant Industry—Continued.

Sample No.	Variety. ¹	S. P. I. No.	Date.		Outside color.		Aver- age weight per fruit.	Specific gravity.	Seed.	Pulp.	Skin.	Edible portion.					Remarks.	
			Picked.	Softened.	Fresh.	Storage.						Mois- ture.	Ash.	Pro- tein.	Fat.	Total su- gar.		Crude fiber.
158	Cabnal	44782	1921. May 5	1921.	Slight purple, dark green.		OUN- ces. 14.69	0.9790	Per cent. 12.43	Per cent. 68.70	Per cent. 18.87	Per cent. 70.49	Per cent. 1.29	Per cent. 1.42	Per cent. 21.98	Per cent. 0.56	Mature.	
157	do.		do.	May 5	do.	Green, dark spots.	16.79	.9806	13.54	65.94	19.85	70.19	1.36	1.70	20.89	.53	1.22	Do.
179	Cabnal (tree 1).		June 30		Green.	Green, slight brown.	10.00	1.0160	14.20	58.98	26.56	70.69		1.38	21.48			Do.
180	do.		do.	July 9	do.		11.90	.9983	15.19	63.72	20.83	71.32		1.27	21.06			Do.
171	Cabnal (tree 2).		do.		Green, brown spots.		9.48	1.0267	16.66	55.84	27.60	75.98		1.29	16.09			Do.
172	do.		do.	July 12	Light green.	Green, dark brown spot.	10.40	1.0103	14.33	60.80	24.54	75.23		1.29	16.26			Do.
145	Tertoh.	44856	May 5		Purple—dark green.	Purple, brown	19.95	.9328	9.53	79.86	10.29	88.34	.92	1.60	4.38	.47	1.05	Immature.
170	do.		June 30	July 12	Green—purple.	Purple.	14.76	.9314	11.89	70.99	17.12	83.46		1.25	8.34			Poor sample.
143	Kanola.	43560	Mar. 8	Mar. 23	One - half purple, one - half green.	Three-fourths purple, one-fourth green.	7.7		12.27	63.64	23.67	70.22	1.32		21.91	.49		Mature.
144	do.		Apr. 6	Apr. 9	Light green.		7.1	.9941	15.10	63.36	21.54	71.50		.97	20.91	.62	1.25	Do.
159	Chilean seed- ling.	43475		May 24	Dark green.	Bright green.	10.78	.9197	13.67	68.37	17.97	79.20	1.24	1.66	13.21	.57		Maturity doubtful.
201	do.		Aug. 22	Aug. 25	Dark green.	Dark green.	13.9	1.0089	7.56	77.33	15.11	73.30		1.99	18.57			Mature.

¹ All these varieties were located at Duarte, with the exception of sample No. 145, located at La Crescenta, Nos. 143 and 144, located at Monrovia, and Nos. 159 and 201, located at Whittier.

DISCUSSION OF RESULTS.

COMPOSITION OF STANDARD VARIETIES TESTED.

The averages of the analyses of the standard varieties of the avocado can not well be used as a basis for comparison, for the reason that samples from some trees were taken while the fruit was immature and those from other trees only when the fruit had become almost ripe. Table 1 was arranged, therefore, to show the order in which each variety ranked with respect to each constituent. The rank is based on either the maximum or minimum figure obtained. The maxima are given in the case of weight, edible matter, protein, and fat; the minima in the case of skin, seed, and crude fiber. When the differences are small, these figures should not be given too much weight, as the relative position of the variety might be changed by another set of data obtained from trees differently located. It might be better, therefore, to rank the varieties by groups only.

When mature, Sharpless, Spinks, and Blakeman average well over a pound to the fruit; Lyon, Fuerte, Taft, and Dickinson, while often reaching a pound in weight, average less, usually about 13 or 14 ounces. Puebla averages about 8 ounces in weight.

Fuerte and Sharpless have the greatest proportion of edible matter, more than 80 per cent. Lyon, Blakeman, Puebla, Spinks, and Taft have between 70 and 80 per cent.

Puebla and Fuerte show less than 6 per cent of skin; Blakeman, Spinks, Sharpless, Taft, and Lyon range from 7 to 10 per cent; and Dickinson exceeds 18 per cent.

Fuerte and Sharpless have the smallest seeds, with Dickinson and Lyon next, each of the four varieties having less than 10 per cent of their weight in seed. Taft and Blakeman run below 15 per cent, while Spinks and Puebla exceed that figure.

When protein is considered, Lyon is the outstanding variety, having more than 4 per cent. In any attempt to increase the protein content of the avocado by bud selection, therefore, this fruit must be considered. When mature, it contains more protein than any other variety yet examined. Spinks, Fuerte, Puebla, and Blakeman are rich in protein, having more than 2 per cent, while the remaining three varieties fall below that figure.

Fuerte leads all other varieties in fat content at maturity, having almost 30 per cent. Lyon and Puebla are also very rich in fat, the best samples containing over 25 per cent. Blakeman, when mature, runs over 20 per cent, while Spinks, Sharpless, and Taft are just below that figure. Dickinson is low in fat, the best sample having less than 15 per cent.

Taft has the smallest amount of fiber, the best sample showing less than 0.75 per cent. Sharpless and Spinks contain a little over 1 per

cent. Puebla, Lyon, Dickinson, and Blakeman have less than 1.25 per cent, Fuerte being the only variety to exceed that amount.

CORRELATION BETWEEN MATURITY AND COMPOSITION.

Even a superficial study of the tabulated data reveals many interesting relations between the composition of the fruit and its maturity. The greatest problem in maturity investigations, however, is the correlation between physical appearance and composition. As a rule it is not hard to decide fairly accurately from its composition at what stage of growth a fruit is in its optimum condition. It is comparatively difficult, however, to correlate this stage with some physical aspect, particularly when the optimum condition desired necessitates the gathering of the fruit some time before it is to be eaten or preserved. All fruit reaches a stage where its maturity is manifest from the physical appearance, but usually when this stage is reached the fruit has passed the optimum condition for long shipment and perhaps even for storage. For instance, when cantaloupes have begun to develop a yellow color on the vine, the time is past when they can be satisfactorily shipped for long distances, and coloring on the tree marks the time when Bartlett pears have passed their best condition for shipping and storage.

Purple or black avocados change in color during growth. An extended study of these varieties might show some correlation between their color and their composition. In the case of green-colored fruit, however, such an opportunity is not afforded. Neither kind can be left on the tree until soft enough to eat, with satisfactory results, for besides the loss of time there is also a noticeable loss in flavor.

The color of the stem has been suggested as an indication of maturity. This may be practical with some varieties, but so far the experience of the authors has led to no definite conclusions in this matter. The stems of some decidedly immature fruit are yellowish, while those of others are green after the fruit has reached a satisfactory state for picking. As far as physical appearance is concerned, it has been impossible to correlate closely any single character or set of characters with maturity.

There is, however, a definite correlation between some other characteristics and ripeness. Thus, the time which elapses after picking, until the fruit becomes sufficiently soft to be edible, roughly indicates whether or not it was in a satisfactory condition when picked. Data in Table 4 show that during growth there is a sharp decline in the time necessary for this softening, but the chart (fig. 1) shows that this change is seldom correlated with the fat content. For instance, in the case of the Fuerte, in February the period elapsing between the time of picking the fruit and the time when it was soft was only 6 days, whereas before that time this period had been from 11 to 16

days. The rapid increase in fat content of this variety, however, ceased in December, and it seems evident that the fruits were in as good condition for eating at that time as in February. On the other hand, the Taft required only 6 days for softening in March, compared with 12 to 19 days in the previous months. The maximum fat content here was not reached until May, however, and the fruit was perhaps ready to eat in April. The Lyon sample for March required 8 days to soften, whereas previously from 12 to 19 days had been required. The maximum fat content was not reached until May, and the fruit was not in satisfactory eating condition until April. It would thus appear that the period required for softening is only an approximate indication of a satisfactory condition for harvesting.

While the fruit of several of the standard varieties was not available in sufficient quantities for satisfactory completion of the tests, enough data were secured from the analyses of Fuerte, Lyon, and Taft to throw some light on the changes which took place as the fruit matured.

Specific gravity of the fruit does not vary with maturity. With one of the varieties there is a possible tendency toward a lower specific gravity in the samples as the fruit becomes thoroughly mature, but this is not the general rule. For instance, with the Fuerte, both the fresh and storage samples tend to decrease in density as the season advances. Starting with a specific gravity of 0.99 or 1, they decrease in a more or less irregular way until the final samples show a density of about 0.96. Most of the other varieties, however, show no such tendency, and it may even be said that the tendency is toward an increase in density as the season advances.

The edible matter increases in all varieties as the fruits mature, but there seems to be no satisfactory line of demarcation which indicates maturity.

The amount of moisture, of course, varies inversely with the amount of fat and therefore decreases with maturity.

The percentage of ash in avocados is relatively small. While it increases with maturity, it is hardly possible to formulate a test with this figure as a basis.

Protein is also higher later in the season than when the fruit is immature. This constituent seems variable, however, and therefore less available for standardizing purposes.

The fat or oil of the avocado, of course, is its chief constituent, and when it has reached its maximum there is no doubt that the fruit is mature. The question arises, however, as to how long before this point is reached the fruit can be harvested with satisfactory results as far as eating and storage qualities are concerned.

When sampling could begin soon enough, the fruits showed a consistent and more or less uniform increase in fat up to a certain point, after which the increase was much less (fig. 1). Often, late in the season, apparent decreases are indicated, showing at least that the increases were not sufficient to overcome the variability of the samples. In the limited experience of the authors, it would seem that the point where the uniform increase in fat ceases is about the point where a satisfactory maturity is found. With the Fuerte this occurred in December, with the Puebla in February, with the Lyon in May, with the Blakeman in May, with the Spinks in March, with the Taft in May, and with the Sharpless in April or earlier. The Dickinson samples afford no data on this point, as the sampling ceased before the fat content had become constant.

The reducing substances or sugars in the pulp of the avocado decrease markedly as the fruit ripens, but the range is hardly sufficient to be of use in estimating maturity. Little or no sucrose is present in avocado pulp.

The crude fiber changes but little during the growth of the fruit, such changes as take place probably being due to the variability of the other constituents. From the data given in Table 3, showing the actual content of fat on a water-free basis, however, it is evident that at the time the rapid increase in fat ceased, the percentages on a water-free basis in the different varieties were, with one exception, close to 70. The following are the figures: Blakeman, 70 per cent; Dickinson, 60 per cent; Fuerte, 75 per cent; Lyon, 70 per cent; Puebla, 73 per cent; Sharpless, 72 per cent; Spinks, 68 per cent; Taft, 72 per cent. It might be supposed from these data that Dickinson was not yet mature, inasmuch as sampling stopped at this time, but miscellaneous samples harvested even later the following year showed a lower content of fat than was shown by these samples. Experience with fully matured fruit of other varieties indicates that avocados rich in fat usually contain at least 70 per cent on a water-free basis, but the rule does not hold when the fat content at maturity is low.

One other source of information concerning changes taking place while the fruit is ripening is afforded by the comparison of the data resulting from the analysis of the fresh and storage samples. When these data are confined to the edible portion of the fruit, the differences are more striking after the data have been reduced to a water-free basis (Table 3). Many interesting phenomena are revealed by a close study of these results. Some of them may be the result of errors in the analyses or of the natural variability in samples consisting of but two or three fruits, but most of them are undoubtedly the result of changes in composition of the fruit after it is removed from the tree. It is hardly practicable to analyze part of one fruit and

store the remainder until it has softened before analyzing it. The best that could be done was to select a lot containing from two to six fruits, as nearly uniform as possible, analyze half this number as soon after picking as possible, and hold the other half until they had become soft. The data must therefore be considered in the light of these facts. Where, however, changes are almost always in one general direction, the probability of their being the result of individual variation is remote.

In all, 40 samples were analyzed at once and after storage, the number being distributed among immature and mature fruits. Some difference between the specific gravity of the fresh and storage fruits of many varieties is shown. In some varieties the storage samples have a much lower specific gravity than the fresh, but in other varieties the reverse is true. Peculiarly enough, also, the position in each type when the fruits are thoroughly mature shows a tendency to reverse itself. Cases in point are the Taft, six samples of which were examined, and the Fuerte, eight samples of which were examined. The Taft samples in September had the same specific gravity, but in October, November, and December fresh samples had a higher gravity than the storage samples picked at the same time, while in May and June the reverse was true. The Fuerte samples for September also had approximately the same specific gravity. The October, November, December, January, March, and April samples of fresh fruit, however, had a lower specific gravity than the storage samples, while in May the reverse was true. Also in the case of the Lyon the fresh samples showed a higher specific gravity until June, when the storage samples had the higher density. On the other hand, the Puebla samples always showed a difference in specific gravity, the soft samples having the higher. Unfortunately, the samples were exhausted before thorough maturity was reached, so that any change late in the season escaped observation. The December samples of the Spinks showed a higher density in the fresh sample, after which the reverse held true.

Omitting the data on the Blakeman, only one double sample of which was examined, the varieties having the heavier skins (Dickinson, Lyon, and Taft) have higher densities in the fresh samples. The thin-skinned fruits (Fuerte, Puebla, and Spinks) show a higher density in the case of the storage samples. Sharpless also is rather thin-skinned, but acts in this respect like a thick-skinned variety.

In several cases the pulp or edible matter increased during storage of the samples. Two factors may account for this—individual variation in the fruit and inability to separate satisfactorily the skin and the pulp in the very green samples. In this connection it will be noticed that the proportion of skin in the storage samples is almost always lower than that in the fresh samples. Of the 40

double samples, the storage fruit had 11.2 per cent of skin and the fresh fruit 13.8 per cent. As the moisture in the pulp was about the same between the two sets, this shows that any loss in weight on standing is largely due to loss of water from the skins.

The proportion of seed is somewhat higher in the storage samples than in the fresh, about 0.8 per cent, being 15.2 for the fresh and 16.0 for the storage. The loss of water from the skin, which increases the relative proportion of the seed, probably is the cause.

The percentage of water in the pulp varies but little. The 40 double samples show about 0.7 per cent more water in the storage than in the fresh samples, a quantity which is probably negligible, as it amounts to only 1 per cent of the moisture content. The percentage of ash is higher by approximately 10 per cent in the storage samples than in the fresh. The only way to explain this discrepancy, which is too large to be accounted for by variation in the samples, is by the difficulty of separating the pulp and skin of the very immature fresh samples. The greater portion of ash in the pulp of the avocado lies next to the skin. If more of the pulp of the fresh samples were left adhering to the skin, less ash would be apparent in the remaining pulp. This difficulty is not encountered in the soft samples, as the pulp is more readily separated. The fact that the greater ash content is nearer the skin, found true in many fruits, has been confirmed in the case of the avocado by analyses made in the laboratory, which showed the outer half of the pulp next to the skin to have 1.54 per cent of ash, as compared with 1.36 per cent of ash in the inner half next the seed, the same avocado being used for each determination.

The protein content shows a somewhat similar change, the average content for the storage samples being approximately 1.8 per cent, while the fresh samples contain but 1.6 per cent. Calculation to the water-free basis does not alter the general ratio between the protein contents of the samples. Another peculiarity of the data is the uniform increase in the protein content of the storage samples of immature fruits over that of the fresh samples. This is particularly noticeable in the case of the Lyon, where the average increase in protein of the storage samples over the fresh is more than 0.4 per cent. With some of the other varieties, this increase is more marked in the case of the immature fruits; after maturity there is in many cases little change, and in some a reverse condition is true. Taking it all in all, the results are inconclusive. It is hard to conceive of a condition where the actual nitrogen content of the fruit could be increased after removal from the tree.

There also seems to be a decided increase in fat content in the storage samples when the fruit is immature, an increase which is not maintained after maturity has been reached. At present it is not

clear whether this is the result of chemical changes occurring during storage or merely of the loss of some other constituent in the fruit. In this connection it is to be noted that the loss of sugar accompanies the increase in fat content and that there is also a decrease in undetermined matter in the storage samples. These losses are not always uniform, however, or in proportion to the increase in fat. When it is recalled that the analyses were necessarily made on different fruits, small inconsistencies can be explained by individual variations in the fruits. The loss is not due wholly to evaporation of water, for the differences are maintained when the data are stated on the water-free basis.

There is some loss in weight in avocados on storage, but the loss of water by evaporation from the pulp is offset by the decomposition of other material. Undoubtedly sugar or at least substances of similar nature are transformed rapidly and are no longer calculated as sugar when the immature fruit is allowed to soften. Such changes often amount to well over 50 per cent of the sugar found. This subject will need further careful study before many questions can be answered. As far as the present investigation goes, it is sufficient to conclude that there appears to be a decided increase in fat content and decrease in sugar content and undetermined matter during the storage of immature avocados. These changes are less marked in the case of the storage of mature fruits, which sometimes show a reversal in the order of the change.

With the amount of work so far accomplished, it is impossible to attempt to recommend a maturity standard on any of the varieties of the avocado. The work here reported covers but one season and one locality for each variety. The data on several of the varieties are decidedly meager.

In the search for promising seedlings and varieties, many miscellaneous samples have been examined in the Laboratory of Fruit and Vegetable Chemistry. Samples of special interest are those of the Guatemalan varieties introduced by the Office of Seed and Plant Introduction of the Bureau of Plant Industry, not a few of which are now in bearing in California.

These samples, the results of the analysis of which are given in Table 6, include the following varieties: Pankay S. P. I. 44785, Benik S. P. I. 44626, Mayapan S. P. I. 44680, Cantel S. P. I. 44783, Nimlioh S. P. I. 44440, Lamat S. P. I. 43476, Cabnal S. P. I. 44782, Tertoh S. P. I. 44856, Kanola S. P. I. 43560, and a Chilean seedling S. P. I. 43475. Of these Pankay, Benik, Mayapan, Lamat, and Cabnal were mature in May, when the first samples were obtained. Cantel and Tertoh were not mature at that time, and there is some doubt as to the maturity of the first samples of Nimlioh. Kanola had every appearance of being mature in February. The second sample of

Tertoh was poor and possibly immature. As will be seen from the table, several of the varieties are rich in oil. Of these Cabnal was believed to have the best flavor. Kanola, while small, also has a good flavor and possibly matures as early as February, when the markets are not glutted with fruit. The protein content of these importations is lower than that of the standard varieties developed in California. They have the heavy skin of the Guatemalan types, which is possibly a marked advantage when shipping quality is considered. The seeds in a number of them are also larger than the average seeds of the types developed in California. All of these fruits are from young trees, and possibly some of the characteristics will be modified as the trees develop.

The analyses of other California types and seedlings are given in Table 5. Many of these are seedlings which have not yet been grown by vegetative propagation, so that it is of little use to comment on their quality. The data, however, are of value to those who are seeking promising experimental material.

CONCLUSIONS.

No satisfactory correlations between physical properties and maturity have been found in the avocados examined.

The proportion of many of the constituents of the avocado changes during its development, the most marked change being the increase of the fat content. This takes place rapidly while the fruit is immature, and much more slowly as it approaches maturity, with possibly a slight decrease if the fruit remains too long upon the tree. It is accompanied by a decrease in sugar content.

Fruits rich in fat (above 20 per cent) contain at least 70 per cent of that constituent on a water-free basis at maturity.

On storage of immature fruits there is an apparent increase in the proportion of fat, accompanied by a decrease in the sugar content and undetermined matter.

Mature fruits on storage do not show this increase to the same extent, and at times show some loss.

No standards of maturity are recommended.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1074



Washington, D. C.

Issued November 8, 1922; revised August, 1923

CLASSIFICATION OF AMERICAN WHEAT VARIETIES.

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NECESSITY FOR A CLASSIFICATION OF WHEAT.

The varieties of wheat grown in the United States show a great diversity of type. This diversity is natural, as wheat is produced commercially in all of the 48 States of the Union, under a wide range of environmental conditions. More than 200 distinct varieties are grown. Many of these are adapted only locally, while others are well adapted to a wide range of varying conditions. This adaptation of a variety is an important factor, as it affects the yield and profitableness of the crop. The choice of varieties for given conditions and purposes, therefore, usually is given careful consideration by growers. The choice, however, is dependent upon the determination of identity.

The identification of varieties requires some knowledge of the appearance of plant and kernel and is assisted by information regarding its history or distribution. Wheat varieties are most generally designated by names, which are established through publication and usage. The association of a name with a recognized type of wheat enables identification. Confusion in names is frequent, especially in America, where the number of actual varieties is very large. This confusion occurs in two principal ways: (1) The same name is applied to very different varieties in different parts of the country, and (2) the same variety is grown under several different names in different parts of the country or even in the same part. Identification is difficult in cases of similar or closely related varieties and is confused by the multiplicity of names.

There is need, therefore, for a practical and usable system of classification which will standardize the varietal nomenclature and enable growers to identify varieties with which they are concerned. The purpose of this bulletin is to provide such a classification of the wheat varieties that are grown commercially in the United States or may be grown soon. The classification has been made by using only such characters as can be distinguished by the naked eye, no instrument other than a measuring rule having been used in the investigations. The names of varieties have been standardized in accordance with a code of nomenclature prepared by Ball and Clark (*43*)¹ and adopted with slight changes by the American Society of Agronomy.

This bulletin is written in response to a demand for varietal information from farmers, agronomists, plant breeders, and members of the grain trade. It should form the basis for future work in wheat improvement, save the time and expense of breeding for combinations of characters which are already in existence, prevent much duplication of work in conducting varietal experiments, and aid in preventing the fraudulent or unknown exploitation of old varieties of wheat under new names. Its greatest value, however, should be in providing a compendium of the wheats of North America for all workers in the wheat industry, especially those who have only a limited or local knowledge of the varieties which are grown.

PREVIOUS INVESTIGATIONS.

Most of the systematic study of wheat varieties has been done by foreign investigators. Comparatively little work of this nature has heretofore been done in America.

¹ The numbers (*italic*) in parentheses refer to "Literature cited," at the end of this bulletin.

FOREIGN CLASSIFICATIONS.*

The existence of many different varieties of wheat has been recognized for more than 2,300 years. Theophrastus (189), a pupil of Plato, in his "Enquiry into Plants," written about 300 B. C., states:

There are many kinds of wheat which take their names simply from the places where they grow, as Libyan, Pontic, Thracian, Assyrian, Egyptian, Sicilian. They show differences in color, size, form, and individual character, and also as regards their capacities in general and especially their value as food.

Theophrastus mentioned many of the differences between these kinds of wheat. In the writings of Varro, Pliny, and Columella, in the first century B. C. and the first century A. D., the observations of Theophrastus were repeated, rearranged, and amplified. Columella, who wrote about 55 A. D. (74, trans. 1745), presents these previous observations and his own, as follows:

Triticum, common bare wheat which has little husk upon it, was, according to Varro, a name given formerly to all sorts of grain beaten or bruised out of ears by trituration or thrashing; but afterwards it was given to a peculiar species of grain, of which there are many sorts, which take their name from the places where they grow; as African, Pontic, Assyrian, Thracian, Egyptian, Sicilian, etc., which differ from one another in color, bigness, and other properties too tedious to relate. One sort has its ears without beards and is either of winter or summer. Another sort is armed with long beards and grows up sometimes with one, sometimes with more ears. Of these the grains are of different sorts; some of them are white, some reddish, some round, others oblong, some large, others small. Some sorts are early ripe, others late in ripening; some yield a great increase, some are hungry and yield little; some put forth a great ear, others a small. One sort stays long in the hose; another frees itself very soon out of it. Some have a small stalk or straw; others have a thick one as the African. Some are clothed with few coats, some with many, as the Thracian. Some grains put forth only one stalk, some many stalks. Some require more, some less time to bring them to maturity. For which reason some are called *trimestrian*, some *bimestrian*; and they say that in Euboea there is a sort which may be brought to perfection in 40 days; but most of these sorts which ripen in a short time are light, unfruitful, and yield very little, though they are sweet and agreeable to the taste and of easy digestion.

In the early Roman literature mentioned reference is found to two groups of wheat, namely, *triticum* and *adoreum*, or *far*. Columella referred to the *far* as bearded wheat. The grain of *triticum* was

* NOTE.—Since this manuscript was completed, two excellent publications on wheat classification have appeared:

(a) Australia. Institute of science and industry. A classification and detailed description of some of the wheats of Australia. Australia. Inst. Sci. and Indus., Bul. 18, 48 p., 4 pl. (1 col.). 1920. Forty-eight of the leading wheats of Australia are classified and described in a manner similar to that used by the writers.

(b) Percival, John. The Wheat Plant. x, 463 p., 228 fig. (in text and on pl.). (1921.) Bibliography, p. 441-453. A large number of wheat varieties of the world are described and classified and the morphology of the wheat plant discussed fully.

In addition to the publications reviewed here, extensive botanical treatises on the taxonomy of wheat forms have been published in Russia by Flacksberger, the most important one being Flacksberger, C., Determination of wheats. *In* Bul. Appl. Bot., v. 8, no. 1/2, p. 9-210 (1-202), 43 fig., 1 col. pl., 1915. In Russian. English summary, p. 183-210 (175-202).

separated from the chaff in thrashing, while that of the *far* was not, indicating that the former consisted of true wheats, while the latter was emmer or spelt.

Columella himself recognized three types of *Triticum*, *robustus* (red), *siliago* (white), and *trimestrian* (spring), and in addition four types of bearded wheat (spelt or emmer), viz:

Clusinian, of a shining, bright, white colour; a bearded wheat, which is called *venunculum*. One sort of it is of a fiery-red colour and another sort of it is white; the *trimestrian* seed, or that of 3 months' growth, which is called *halicastrum*.

It is evident from these quotations that many of the leading characters of the wheat plant were recognized in this early period. What attention was given to studies of wheat during the Dark Ages no one can say. With the revival of learning the botanists and medical men began the publication of the folio and royal octavo herbals, many of them illustrated with woodcuts. In these, wheat species were included, the forms mostly being those described by Theophrastus, Pliny, and Varro, but from time to time new ones were added. There is little advantage in trying to guess what particular form of common wheat each so-called species represented. More recent botanical writers described species which can now be recognized. Principal among these writers was Tournefort (194), who in 1719 listed 14 species of *Triticum*.

The classification of wheat practically began with the work of Linné in 1753. In his *Species Plantarum* (140) he described seven species of *Triticum*, viz: *T. aestivum*, *T. hybernum*, *T. turgidum*, *T. spelta*, *T. monococcum*, *T. repens*, and *T. caninum*. The two latter species have since been included in another genus. In the second edition of the *Species Plantarum*, published in 1764, he describes six species which are still included in the genus *Triticum*, viz: *T. aestivum*, *T. hybernum*, *T. turgidum*, *T. polonicum*, *T. spelta*, and *T. monococcum*, the species *T. polonicum* having been added. Linnæus divided the common wheat, *T. vulgare*, into two species, *T. aestivum*, awned spring, and *T. hybernum*, awnless winter, apparently believing that all spring wheats were awned and all winter wheats awnless. Writers who followed him usually have not recognized these distinctions.

Lamarck, in 1786 (134), created the species *Triticum sativum* to include both the species *T. aestivum* and *T. hybernum* which Linnæus had adopted. Each species and subspecies was described according to the presence or absence of awns, the color and covering of the glumes, the color, size, and density of the kernels, the solidity of the stem, and several other characters.

Villars, in 1787 (198), divided the common wheats into two species, *Triticum vulgare* and *T. touzelle*. The latter consisted of awnless wheat having white kernels.

Desfontaines, in 1800 (79), established the species *Triticum durum* for the group of wheats having long awns and long vitreous kernels.

Host, in 1805 (119), described and named the species *Triticum compactum* to include the club wheats and in addition recognized 10 other species of the genus *Triticum*.

Seringe, in 1819 (174), arranged the common and club wheats together into 10 groups based on lax or dense and awned or awnless spikes, white or brownish kernels, and glabrous or pubescent glumes. He listed varieties from Switzerland, France, Germany, and England.

Metzger, in 1824 (143), at Heidelberg, followed essentially the same system as Seringe, but in addition considered winter or spring habit of growth. The 10 groups of Seringe were further subdivided, making 18 groups. The kernels were described as white, yellow, and reddish.

Metzger, in 1841 (144), reedited his classification of 1824, making some changes and adding more varieties.

Seringe, in 1841 (175), published a revision of his previous work of 1818, in which he classified and partly described a large number of varieties of wheat.

Alefeld, in 1866 (35), classified the wheats into two genera and species, *Triticum vulgare* and *Deina polonica*. The latter contained four subspecies or varieties of Polish wheats, *T. polonicum*, while the former was divided into many subspecies and varietal groups containing all other species of *Triticum*. Each of these was described in detail.

Heuzé, in 1872 (111), grouped the wheats into 7 species. He listed 700 varietal names of wheat, 602 of which belonged to the species *Triticum sativum*, which included both common and club wheats. He described 47 varieties in this species, while the remaining 555 names were considered as synonyms.

Koernicke, in 1873 (132), and Koernicke and Werner, in 1885 (133), prepared the most complete classification of wheat yet published. They followed Alefeld's system of applying Latin names to the botanical groups. The groups keyed by them included 22 of *vulgare*, 21 of *compactum*, 26 of *turgidum*, 24 of *durum*, 12 of *spelta*, 20 of *dicoccum*, 21 of *polonicum*, and 4 of *monococcum*. Named varieties included in each botanical group were described in detail, and the history, synonyms, and source of each were given. Much of this latter information had been published in the works of Alefeld and Heuzé.

Harz, in 1885 (104), classified and described a large number of wheats in a manner similar to that of Koernicke and Werner. The common and club wheats were considered as a single species.

Hackel, in 1887 (101), classified the genus *Triticum* according to a key very similar to the one adopted by Koernicke and Werner. Hackel recognized three species, *sativum* Lam., *monococcum* L., and *polonicum* L.; and three races of *sativum*, namely, *spelta*, *dicoccum*, and *tenax*. In the latter he included *vulgare*, *compactum*, *turgidum*, and *durum* as subraces.

Vilmorin, in 1889 (199), grouped the wheats into 50 sections, according to their leading characters. Each section was briefly described and the synonyms were given. The common and club wheats were considered as one species.

Eriksson, in 1895 (88), subdivided the botanical groups of Koernicke and Werner into smaller groups which he called subvarieties, based chiefly on the density of the spike, the thickness of the kernel, and the length of the rachis. He also gives an excellent review of the literature on wheat classification.

Heuzé, in 1896 (112), published a second edition of his "Les Plantes Céréales," in which were included rather complete histories and descriptions of the varieties of wheat.

Cobb, in 1896 (69), keyed 54 varieties of wheat which he was growing in New South Wales, Australia, using the leading plant, spike, and kernel characters. In 1905 (72) he proposed to classify wheat varieties by a microscopic examination of the aleurone layer. This method, however, is impracticable for classification purposes in the field, or even with certainty in the laboratory, when closely related varieties are considered.

Howard and Howard, in 1909 (121), classified the wheats of India largely according to the methods of Koernicke and Werner and of Eriksson. They (120) also consider in detail the characters used in classification.

Richardson, in 1913 (158), described many of the wheats of Australia and gave the history of each variety. He did not arrange them in a classified order.

The Union of South Africa in 1919 (181) published descriptions and synonyms of the wheat varieties of South Africa which also designated the areas where the varieties should be grown in that country.

Ducellier, in 1920 (82), published a classification and descriptions of the wheats of the Hoggar and oasis regions of Algeria. Only a few varieties were fully described.

AMERICAN CLASSIFICATIONS.

Harmon, in 1844 (103), published descriptions and histories of about 30 varieties of wheat which he had grown in Monroe County, N. Y.

Klippart, in 1858 (131), described a large number of wheat varieties grown in Ohio and grouped them into a partly classified order.

Todd, in 1868 (193), described a number of wheat varieties, most of the descriptions, however, being obtained from agricultural literature of the time. He suggested that the Government "take hold of this subject [the nomenclature of wheat] in a proper manner and establish a common standard of merit and an intelligible description of each variety . . ."

Killebrew, in 1877 (130), described a number of American wheats, most of which had been described previously by Klippart or Todd. He grouped the varieties into two families, winter wheats and spring wheats. The winter wheats were divided into six classes based upon their kernel characters, white, amber, and red, and upon the awned or awnless character. The spring wheats, which were all regarded as being awned, were placed in three classes, with white, amber, or red kernels.

Tracy, in 1881 (195), listed a number of wheat varieties grown by him at the Missouri Agricultural Experiment Station. The varieties were partly described, showing the "bearded" or "smooth" heads and the color and size of the kernels. He mentions several varietal names as being synonymous.

Devol, in 1887 (80) and in 1888 (81), published a classification of the wheat varieties being grown at the Ohio Agricultural Experiment Station. This classification was further developed by Hickman (113), who in 1889 divided the varieties into eight morphological groups.

Plumb, in 1889 (153), described a large number of wheat varieties, chiefly American, and gave the histories of many of them.

Blount, in 1892 (47), listed 478 varieties of wheat which he was growing experimentally in New Mexico. Histories of some of these were given.

Carleton, in 1900 (58), summarized the varietal information of that time, listed about 350 varieties, gave their source by countries and their principal characters, and grouped them by districts of the United States to which they are best adapted.

Scofield, in 1902 (172), classified and described a large number of durum wheats grown in Algeria, many of which were introduced into the United States about 1901. He also described the characters used in classification. In 1903 Scofield (173) prepared a detailed list of characters to be used in the description of wheat varieties. He

did not publish the descriptions of any varieties at that time. The application of the terminology was partly illustrated by plates accompanying the article.

Williams, in 1905 (204), listed and partly described about 60 varieties of wheat which were under experiment at the Ohio Agricultural Experiment Station at that time.

Hume, Center, and Hegnauer, in 1908 (122), briefly classified the wheat varieties grown in experiments in Illinois, and gave the history and partial descriptions of some of the Russian and American varieties.

Scherffius and Woosley, in 1908 (171), published illustrations of 36 varieties of wheat grown by the Kentucky Agricultural Experiment Station.

Noll, in 1913 (149), presented a tabular description of varieties grown by the Pennsylvania Agricultural Experiment Station.

Leighty, in 1914 (138), gave a list of the leading varieties of wheat grown in the eastern half of the United States, arranging them in classified groups by kernel and spike characters.

Schafer and Gaines, in 1915 (170), recorded brief descriptions of the principal wheat varieties of Washington, together with their histories.

Nelson and Osborn, in 1915 (148), gave a brief tabular description of the wheat varieties grown at the Arkansas Agricultural Experiment Station during the period from 1908 to 1914.

Reisner,² in 1915, compiled much valuable information on the description and history of New York varieties.

Ball and Clark, in 1915 (39), presented keys to the groups of hard red spring wheat and the durum wheats grown in the United States and described and gave the histories of the more important varieties.

Carleton, in 1916 (61), listed the leading wheat varieties of the world, including American varieties. They were grouped into the botanical groups used by Koernicke and Werner. No attempt was made to distinguish between the closely related agricultural varieties.

Stanton, in 1916 (135), grouped a large collection of wheat varieties grown in experiments in Maryland and Virginia, in accordance with some of the most obvious taxonomic characters.

Jones, in 1916 (129), presented a brief key to the groups of common spring and durum wheats grown in experiments in Wyoming.

Ball and Clark, in 1918 (42), published a key to the groups and varieties of durum wheat grown in the United States.

Grantham, in 1918 (99), listed a large number of varieties which were being grown at the Delaware Agricultural Experiment Station

² Reisner, John H. Wheat in New York. 1915. Unpublished thesis, Cornell University. The writers wish to here acknowledge the use of this manuscript, credit being due to both the author and the Farm-Crops Department of Cornell University.

and stated whether they were bearded or smooth, and also the color of the grain and chaff, the height of the plant, and the weight of the kernels.

Clark, Stephens, and Florell, in 1920 (67), gave a tabular description of over 150 samples of Australian wheat varieties grown in experiments in the Pacific coast area of the United States.

Clark, Martin, and Smith, in 1920 (66), keyed the groups of common spring and durum wheat grown in experiments in the northern Great Plains area of the United States, and gave the histories of the principal varieties.

Stewart, in 1920 (187), presented keys and brief descriptions of the commercial wheat varieties grown in Utah.

SUMMARY OF PREVIOUS CLASSIFICATIONS.

From the beginning of botanical classification there was a tendency to regard the different forms of wheat as distinct species. Toward the end of the eighteenth century there became evident a tendency toward the more reasonable view that comparatively few species were involved and that the evident major groups were mostly to be regarded as subdivisions of the species *sativum* of Lamarck or *vulgare* of Villars.

The making of botanic species of wheat was carried to great lengths by the botanists of 100 to 200 years ago, who did not recognize that the characters sufficient to separate species of wild plants were sufficient to separate only agronomic and horticultural varieties of domesticated plants. Before this fact was recognized and botanists very largely had ceased to deal with the forms of cultivated plants, some 50 or 60 supposed species of wheat had been described.

In the works of most of the botanists there was little effort to study and describe the farm varieties of wheat. However, Heuzé, Koernicke and Werner, Eriksson, Richardson, and others described many varieties, and some of their descriptions were fairly complete. No attempt has been made, however, previous to the present work, to show by detailed keys and by uniform descriptions the minor differences which separate closely related varieties.

There has been wide diversity among botanists in the taxonomic use of the various morphological characters of the wheat plant and seed. Only a few authors have given attention to the winter or spring habit of growth in wheat varieties. Some, as Eriksson, have placed undue importance on differences in spike density. Many writers have made no use of the colors of the seed coat in separating varieties.

The classification of Koernicke and Werner is the most extensive and the only one which made a definite attempt to describe and classify foreign and domestic farm varieties. While conservative

to the extent of reduction of the number of species, these authors still maintained a complete Latin nomenclature for forms as far as the fifth rank. In their discussions, these authors, as well as other investigators named, were handicapped through making their studies in only one locality. In the present work, the varietal descriptions are based on the expression of each variety under the widely varying conditions of environment found in different parts of the United States.

PRESENT INVESTIGATIONS.

The present investigations were started in 1915³ with the object of making a classification of the wheats of the world. During the first two years much time was devoted to a study of foreign varieties, and several hundred introductions were added to the large collection of foreign wheats previously obtained. In the third year the study was devoted largely to diverse botanical types obtained from hybrids or distinct types found as mixtures in wheat fields in the western United States. It was soon determined, however, that if the studies were to be of economic value, they must be limited to the principal cultivated varieties. The World War prevented the completion of the introduction of foreign wheats, so it was finally decided to limit the present publication to the commercial American varieties. In the spring of 1919, a "Preliminary classification of American wheat varieties,"⁴ containing a key to varieties and index, was prepared in mimeograph form, and about 100 copies distributed to agronomic workers. Suggestions and corrections were invited. Several changes which were suggested have been incorporated.

Hundreds of foreign and domestic varieties have been grown, studied, described, and classified, and herbarium specimens have been preserved in a classified order. Many of these varieties, however, are not included in this bulletin. During the past three years the

³ The plan to classify wheat varieties was evolved by Carleton R. Ball, agronomist in charge of Western Wheat Investigations, in the summer of 1914, while studying a large number of foreign and domestic varieties in breeding nurseries at experiment stations in the western United States. In July of that year J. Allen Clark became his assistant, and the classification was carried on jointly until April, 1918, when Mr. Ball was promoted to the position of cerealist in charge. Since that time the classification has been continued by Mr. Clark, who was placed in charge of Western Wheat Investigations, and by John H. Martin, who became his assistant in February, 1919.

During the entire investigation the fullest cooperation has been received from Dr. C. E. Leighty, agronomist in charge of Eastern Wheat Investigations, who has furnished numerous varieties, much information on varietal history and synonymy, and some assistance with the nurseries in the Eastern States.

In the preparation of the manuscript of this classification C. W. Warburton has rendered valuable editorial assistance. The drawings were made by Mrs. R. E. Gamble and the photographs, unless otherwise indicated, were taken by E. L. Crandall. These services are all gratefully acknowledged.

⁴ Clark, J. Allen, Ball, Carleton R., et al. Preliminary classification of American wheat varieties, 20 p. 1919. (U. S. Dept. Agr., Off. Cereal Invest. Mimeographed circ.)

commercial varieties have been given the most careful study. Many varieties not previously known were obtained and grown. Each year the varieties studied during the preceding season, with all new material obtained, were grown in the classified order presented herein. Each year, therefore, the classification became more definite and complete. There still remains much to be learned about the American varieties, but it is thought that publication of the information compiled to date should no longer be delayed.

CLASSIFICATION NURSERIES.

Classification nurseries have been grown in several widely separated sections of the United States. This was necessary in order to determine the expression of varieties under different environments and thus embrace a scheme of classification which would be workable wherever the varieties happened to be grown. It also guarded against the loss of certain types, which often results if wheat is grown at only one place. In Table 1 is shown the location of 18 experiment stations where classification nurseries have been sown, as well as the annual and total number of sowings which were made.

TABLE 1.—*Annual and total number of rows sown in the classification nurseries of fall and spring wheat at one or more of 18 experiment stations in the United States during the 6-year period from 1915 to 1920, inclusive.*

Station.	1915		1916		1917		1918		1919		1920		6-year total, fall and spring.
	Fall.	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.	Spring.	Fall.	Spring.	
Chico, Calif.....	146	.....	790	.....	902	.....	950	.....	720	720	1,419	.....	5,647
Corvallis, Oreg.....							944	1,091	495	495	480	480	3,985
Moro, Oreg.....		152	691	313	1,804	554	950	1,091	495	.....	235	480	6,765
Pullman, Wash.....									186	.....	126	109	421
Aberdeen, Idaho.....		164	307	313	.....	.....	.....	.....	.....	.....	.....	.....	784
Nephi, Utah.....			430	.....	.....	.....	.....	.....	.....	.....	.....	.....	430
Bozeman, Mont.....											126	.....	126
Moccasin, Mont.....		680	.....	619	.....	.....	.....	.....	.....	.....	.....	.....	1,299
Akron, Colo.....			302	.....	.....	.....	.....	.....	.....	.....	.....	.....	302
Fort Collins, Colo.....											126	.....	126
Williston, N. Dak.....						554	.....	.....	.....	.....	.....	.....	554
Dickinson, N. Dak.....		787	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	787
Newell, S. Dak.....				619	.....	.....	.....	.....	.....	.....	.....	.....	619
St. Paul, Minn.....		657	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	657
Manhattan, Kans.....			534	.....	.....	.....	.....	.....	.....	.....	.....	.....	534
Amarillo, Tex.....		550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	550
Arlington Farm, Va.....					736	.....	523	.....	.....	.....	235	.....	1,494
Ithaca, N. Y.....					301	.....	.....	.....	.....	.....	.....	.....	301
Total.....	146	2,990	3,054	1,864	3,743	1,108	3,367	2,182	1,896	1,215	2,747	1,069	25,381

Table 1 shows that during the six years 1915 to 1920 more than 25,000 separate sowings were made. Most of these were made at experiment stations in the western United States. The greatest number of sowings at any one station, totaling 6,765, was made at the Sherman County branch station at Moro, Oreg.; the second greatest, 5,647, at the Plant-Introduction Garden, Chico, Calif.; and the third

greatest, 3,985, at the Oregon Agricultural Experiment Station, Corvallis, Oreg. At these western points growing conditions were much better for classification purposes than at eastern points. The absence of summer rains in the Western States is the principal reason for this, as plant characters and colors are more distinctly developed. At Chico, Calif., and Corvallis, Oreg., there was the added advantage of being able to sow both winter and spring wheats in the fall without danger of losing the spring forms. At Moro, Oreg., spring wheats sometimes survived from fall sowing also. At the latter point much valuable information was obtained from spring sowing of wheats having a winter habit. These studies were found to be necessary to determine accurately the true plant habit of some varieties.

The classification nurseries were sown in short rows, usually not exceeding 5 feet in length and a foot or 18 inches apart. At the stations where all varieties were sown both in fall and spring, each variety was sown in the spring on one end of the row sown in the fall. Plate I shows portions of the classification nursery at Corvallis, Oreg., in 1919. Figure A of Plate I shows spring wheat fall sown and spring sown, the fall-sown portion being on the right and the spring-sown portion on the left. Figure B of the same plate shows winter wheat spring sown and fall sown in the same manner.

ASSISTANCE RECEIVED.

To obtain samples of the different wheat varieties was the first important task. This was accomplished with the assistance of many individuals and institutions.⁵

The classification nurseries at the various stations usually were sown by local representatives.⁶ The local men also took notes on

⁵ The writers have obtained samples of seed and cooperation in other ways from officers of the divisions of grain standardization and grain supervision, Bureau of Markets, of the U. S. Department of Agriculture. Samples also have been obtained from most of the State agricultural experiment stations in the United States and the Dominion Department of Agriculture in Canada, and the writers wish here to express thanks to the officers of these many institutions who have so kindly assisted in this work.

⁶ The writers wish to acknowledge gratefully the cooperation of field men of the Office of Cereal Investigations. To Mr. D. E. Stephens, superintendent of the Sherman County branch station, at Moro, Oreg., and to Mr. V. H. Florell, assistant agronomist, in charge of the cereal investigations at the Plant-Introduction Garden, Chico, Calif., special credit is due and is here gladly given. Other station men who have assisted in these studies are Mr. F. J. Schneiderhan, formerly scientific assistant, in charge of the cereal-breeding nursery at Moro, Oreg.; Mr. L. C. Aicher, superintendent of the Aberdeen substation, Aberdeen, Idaho; Mr. J. W. Jones, formerly superintendent of the Nephi substation, Nephi, Utah; Mr. N. C. Donaldson, formerly scientific assistant, in charge of the cereal experiments at the Judith Basin substation, Moccasin, Mont.; Mr. George A. McMurdo, formerly assistant, in charge of the cereal investigations at the Akron Field Station, Akron, Colo.; Mr. F. R. Babcock, formerly scientific assistant, in charge of the cereal studies at the Williston substation, Williston, N. Dak.; Mr. Ralph W. Smith, assistant agronomist, in charge of the cereal experiments at the Dickinson substation, Dickinson, N. Dak.; Mr. J. H. Parker, formerly scientific assistant, in charge of the breeding for rust resistance in cereals at the University Farm, St. Paul, Minn.; Mr. Louis Wermilskerchen,

A

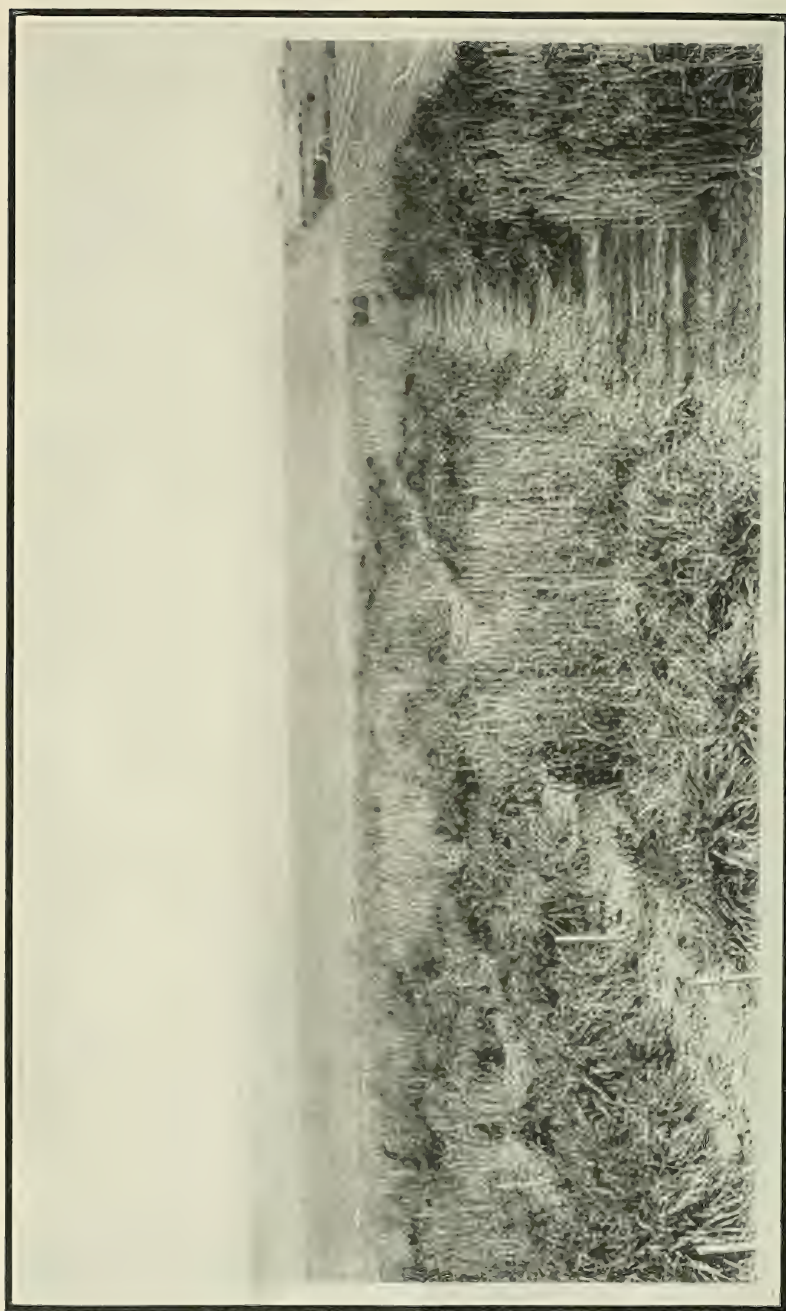


B



WHEAT-CLASSIFICATION NURSERY AT CORVALLIS, OREG., IN 1919.

A, Varieties of winter wheat grown from spring (1) and fall (2) sowing. B, Varieties of spring wheat grown from spring (1) and fall (2) sowing. (Photographs by J. A. Clark.)



WHEAT-CLASSIFICATION NURSERY GROWN AT MORO, OREG., IN 1918.

The winter habit of winter-wheat plants from spring sowing is here shown. (Photographed by D. E. Stephens.)

emergence, heading, ripening, and height of the many varieties. During the summer the writers visited the various points and took detailed notes on the characters of the varieties. It was here, in the field, that the descriptions of the varieties were written and the keys designed and perfected to distinguish the different varieties. The descriptions were checked and rechecked at the various points and the different descriptive classes were established on a basis broad enough to include the varieties wherever they were grown.

NATURE OF THE MATERIAL.

The early studies showed the necessity of working with pure lines. When bulk seed was used it often consisted of mixed varieties and a wrong description might easily become applied to a variety. For that reason careful notes were made on the material that was sown in each nursery. A typewritten outline was prepared each year which showed the classified arrangement of the varieties based on the results to date and also the row numbers at each station. The same variety often was represented by different lots of seed obtained from different sources. These were distinguished by different C. I. numbers, which are accession numbers of the Office of Cereal Investigations. The varieties, however, have always been distinguished by names rather than by numbers. For this reason Cereal Investigation numbers are not used in this publication. The nursery outlines also contained columns showing the source of the seed sown and the original source of the variety. In addition, they showed whether the seed sown was bulk grain or a pure line, and if a pure line, whether the same pure line was sown at all stations or whether different pure lines were used. In this way it was easily possible to compare field notes accurately with those of the previous year or to account for differences which existed in the same variety at different stations in the same year. This latter condition often occurred when bulk grain or different pure lines were used. Natural field hybrids thus were easily distinguished from mixtures.

formerly scientific assistant, in charge of the cereal nursery at the Amarillo Cereal Field Station, Amarillo, Tex.; Mr. A. D. Ellison, formerly scientific assistant, Mr. H. P. Ames, formerly agent, and Mr. J. W. Taylor, scientific assistant, respectively, in charge of the cereal investigations at the Arlington Experimental Farm, near Rosslyn, Va.; Dr. H. H. Love, professor of plant breeding, and Mr. W. T. Craig, agent, Cornell University, Ithaca, N. Y.

The writers also acknowledge with gratitude the assistance received from the following officers of the State experiment stations not formally cooperating with the Office of Cereal Investigations: Prof. G. R. Hyslop, professor of farm crops, and Prof. C. C. Ruth, assistant professor of farm crops, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.; Prof. E. F. Gaines, assistant professor of farm crops at the Washington Agricultural Experiment Station, Pullman, Wash.; Prof. P. V. Cardon, agronomist at the Montana Agricultural Experiment Station, Bozeman, Mont.; Mr. Breeze Boyack, formerly assistant agronomist at the Colorado Agricultural Experiment Station, Fort Collins, Colo.; and Prof. S. C. Salmon, professor of farm crops at the Kansas Agricultural Experiment Station, Manhattan, Kans.

After growing, for a couple of years, several pure-line strains of the same variety obtained from several sources, one of the strains was selected as the standard for the variety. The descriptions here recorded, therefore, should represent the true type of the variety. In certain cases, however, material was limited to samples obtained from only one or two sources, and in these cases the judgment of the writers in selecting the pure strain which correctly represents the variety may not be as accurate as where more samples of the same variety were available.

Many varieties here described are badly mixed in commercial fields wherever they are grown. Mention of this sometimes is made in the descriptions. In many cases this will account for differences observed between a variety and its description, as here recorded. In other cases all the characters which are here recorded may not become apparent in some localities, and this may cause some confusion. The failure of stem and glume colors to develop in some sections is an example of this.

Natural crossing between wheat plants occurs quite commonly in the western United States. In the classification nurseries several hybrid rows have been found each year. These had been sown from material which was apparently pure the previous season and which was grown from a single head. In some instances the hybrids were not noticed until the second generation when they were segregating. This natural crossing has caused some difficulty in describing varieties, especially because hybridization between closely related varieties could not always be detected.

Several hundred mixtures obtained from experimental plats and commercial fields were grown in the classification nurseries for identification. A few proved to be mechanical mixtures of varieties grown in the locality, but most of these were new types. These probably originated, for the most part, from natural hybrids, with possibly an occasional mutation. Many of the types continued to segregate, thus proving their hybrid origin. Those which came true to type were either mutations or the homozygous progeny of hybrids. As the progeny of a cross nearly all tend to become homozygous after being grown several years, it is believed that practically all of the new types can be accounted for in this way. Many of the new types closely resembled American or foreign varieties, but were not identical in all characters.

Practically every field of wheat contains some plants which can not be identified with any known variety. These are easily found, because of their differences from the remainder of the plants in the field. Many of these forms, in all probability natural hybrids or mutations, have been submitted to the writers for identification, but as a rule this is not possible. Considering the opportunities for the

natural and artificial production of new forms, the number of distinct varieties of wheat existing in the United States is not surprising. It is really remarkable to find so comparatively few in commercial cultivation. By making all possible combinations of the characters used by the writers in describing the wheat varieties, several thousand new varieties could be produced.

PREPARING DESCRIPTIONS, HISTORIES, AND DISTRIBUTIONS.

For each variety there is given the description, the history so far as known, the distribution in the United States, and the synonymy.

PREPARATION OF VARIETAL DESCRIPTIONS.

Detailed descriptions have been written of the wheat varieties here enumerated. These descriptions contain much more detailed information concerning the nature of the varieties than is included in the keys and are necessary for a clear knowledge of the appearance of the varieties. The descriptions are not complete, however, several of the morphological characters of the wheat plant not being included because they are of little or no value in classification. Only the more important taxonomic characters are used. This has made possible shorter and more concise descriptions than would otherwise be possible. However, they are thought to be sufficiently inclusive to provide a comprehensive knowledge of the different varieties.

Following the descriptions of many varieties is a paragraph showing the chief characters which distinguish the variety from closely related ones. This gives the reader a more ready comparison of certain varieties than is otherwise possible.

PREPARATION OF VARIETAL HISTORIES.

The history of the origin of varieties can not be neglected in a complete classification, as many varieties are scarcely or not at all distinguishable from similar or closely related varieties and differ only in their origin or qualities. In this study much attention has been given to the history of varieties, and to many readers it probably will be the most interesting and valuable part of the classification. The compiling of these histories has been a long and arduous task. It has required a review of the literature on wheat varieties written during a period of more than 200 years. The sources of this information are varied. Definite information is readily available on the origin of only a comparatively few varieties. Introductions of foreign varieties have been recorded in recent years by the Office of Foreign Seed and Plant Introduction. Frequent reference is made to the accession numbers and published inventories of that office. Many bulletins of the State agricultural experiment stations have

contained valuable information on the origin of domestic varieties. Agricultural papers have been reviewed, and much information as to the origin of varieties has been obtained from that source. There is still much to learn concerning the origin of our cultivated varieties. The origin of many probably has never been recorded, but of some for which the origin has not been determined there probably is a recorded history somewhere. Reference is always given to the published sources of the histories that have been obtained.

DETERMINATION OF DISTRIBUTION OF VARIETIES.

The commercial distribution and production of different varieties are the greatest economic factors with which this classification is concerned. Those varieties which are most widely grown usually are the most valuable. Varieties that are more productive may be in existence, but until they become known and widely grown they are of little value. New varieties are being continually produced. Some are of little or no value. Others are an improvement over the older standard varieties, as their use extends the area of wheat culture, increases the yield per acre, or improves the quality. This adds to production and increases the income of the producer.

The commercial success of varieties is largely dependent upon their adaptation to the conditions in which they are grown. A variety that produces well in a locality soon becomes well known and its acreage increases until it comes into competition with other varieties which are more productive. The production of old, well-adapted varieties is rather extensive and stable. Their distribution has become fixed within certain general sections. New varieties are still competing for supremacy and therefore are more locally and sparingly grown. Poorly adapted varieties sometimes have continued in cultivation for more than a century in isolated and unimportant wheat-producing localities. The distribution of these, therefore, is often widely scattered.

THE VARIETAL SURVEY.

To determine the commercially cultivated varieties of wheat in the United States and the extent of their distribution, a wheat varietal survey was made in cooperation with the Bureau of Crop Estimates. The first survey was made in 1917, when questionnaires were sent to one or two correspondents in each of the wheat-producing counties of the various States. The incomplete returns from this survey were very interesting and contained so much valuable information from the counties reporting that it was decided in 1918 to send questionnaires to several correspondents in all counties not previously reporting, in order to have a more complete record. The replies were received and tabulated. They showed the varieties

grown in the localities of the county where the correspondents lived, but it was soon determined that all of the varieties grown in the county were not included and that one or two reports from each county did not give an accurate estimate of the proportionate distribution of the different varieties. It was finally decided in 1919 to determine rather accurately the percentage each variety formed of the total wheat crop of each county. A new schedule was printed for this survey and about 70,000 were mailed. To the more important wheat-growing counties as many as 30 to 40 questionnaires were sent, fewer being sent to counties less important in wheat production. From the survey about 40,000 returns were received. About 19,000 of these gave definite information, and these results have been tabulated. In addition to the names of varieties grown and the percentage each formed of the total wheat crop, the questionnaires contained tabular spaces for descriptions of varieties. From these descriptions the correct naming of the variety was checked. Figure 1 shows a copy of one of the returned schedules. The reports were edited before being tabulated and thus many recognizable mistakes were corrected. The summary of these reports revealed a large number of new names used for old varieties and also brought to light several wheats distinctly different from any of the varieties previously obtained. More than a thousand letters were written to the correspondents, requesting samples and additional information. A considerable number of additional varieties were obtained in this way.

The distribution of the different varieties shown in this publication was obtained from these surveys. The maps which illustrate the distribution of the varieties were made on the basis of one dot for every thousand acres or less in each county where the variety was grown in 1919.

VARIETAL NOMENCLATURE.

Wheat varieties must be distinguished by names. These names must be used frequently by agronomic workers, as well as by a host of crop growers and crop users. The form and appropriateness of these names, therefore, are of general interest. It is desirable that they be short, simple, and appropriate, easily spelled and pronounced. It also is desirable that, as far as possible, a single name be accepted and used for each recognized variety.

The multiplication of names and other designations for crop varieties has already been carried to great extremes. The resulting confusion is very great, especially in wheat, where the number of actual varieties is very large. In addition to the confusion of names, many names are objectionable. Many varietal designations are merely descriptive phrases which are often long and cumber-

[A. S.—5189.]

**UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF CROP ESTIMATES.**

WHEAT VARIETY SURVEY SCHEDULE.

TO BE MAILED PROMPTLY.

WASHINGTON, D. C., March, 1919.

DEAR SIR: The Department of Agriculture wishes to learn more about the wheat crop and the changes that are taking place in varieties being grown.

To the wheat-growing industry this is very important. Every schedule properly filled and promptly returned will make the results of greater value. It is hoped that you will cooperate by filling the schedule as completely as possible and returning it in the inclosed envelope, which requires no postage.

If you are unable to give the information asked, but know some one in the county who can, will you please refer this schedule to him. If no wheat is grown in your county, please return this schedule, writing across it "No wheat."

Respectfully,

LEON M. ESTABROOK, Chief of Bureau.

QUESTIONS.

(Insert answers for your own community in tabular form below.)

A. What wheat varieties are grown in your locality?

B. What percentage of the total wheat acreage in your locality does each variety represent?

C. Please describe the varieties named by writing in the columns below the proper word, as "Winter," "Spring," or "Both," and so on for head, chaff, and kernel characters.

WHEAT VARIETIES.

No.	A NAME OF VARIETY.	B PERCENTAGE IN FORMS OF TOTAL WHEAT CROP.	C DESCRIPTION OF VARIETIES.			
			PLANT.	HEAD.	CHAFF.	KERNEL.
			Winter or spring, or both.	Bearded or beardless.	Smooth or hairy. White or brown.	White or red.
1	Wartyfold	80	winter	beardless	smooth brown	white
2	Little Club	10	both	"	" white	"
3	Marquis	5	spring	"	"	red
4	Junkins Club	2	both	"	" brown	white
5	Sanora	2	spring	"	hairy	"
6						
7						
8						

ADDITIONAL INFORMATION.

Any further facts you can give about these varieties will be appreciated. For instance, if any of them are used only, or chiefly, on some particular kind of soil, please tell that fact. If any of them are newly introduced in the community, please tell where and when they were obtained. (Back of this sheet may be used for this purpose.)

Name Bernal D. Hug County Union

Post Office Elgin State Oregon

I live miles (North, south.) and 3 miles East (East, west.) from this post office.

FIG. 1.—A returned questionnaire of the wheat varietal survey.

some. Others are only numbers, which sometimes are equally long and cumbersome or are easily confused. Because of this condition, a code of nomenclature was proposed by Ball and Clark (43), so that in this classification varietal names could be selected in accordance with its rules. The code was presented to the American Society of Agronomy at its annual business meeting on November 13, 1917. After a few minor changes were made by the committee on varietal nomenclature, it was adopted by the society (37) as follows:

CODE OF NOMENCLATURE.

1. **ELIGIBILITY TO NAMING.**—No variety shall be named unless (a) distinctly different from existing varieties in one or more recognizable characters, or (b) distinctly superior to them in some character or qualities, and (c) unless it is to be placed in commercial culture.
2. **PRIORITY.**—No two varieties of the same crop plant shall bear the same name. The name published (see par. 4) for a variety shall be the accepted and recognized name except in cases where it has been applied in violation of this code.
 - A. The term "crop plant," as used herein, shall be understood to mean those general classes of crops which are grouped together in common usage without regard to their exact botanical relationship, as corn, wheat, sorghum, cotton, potato, etc.
 - B. The paramount right of the originator, discoverer, or introducer of a new variety to name it, within the limitations of this code, shall be recognized.
 - C. Where the same varietal name has become thoroughly established for two or more varieties, through long usage in agronomic literature, it should not be displaced or radically modified for either one, except where a well-known synonym can be substituted. Otherwise the varieties bearing the same name should be distinguished by adding some suitable term which will insure their identity.
 - D. Where several well-established names are used for the same variety the list of synonyms shall be submitted to some committee of the American Society of Agronomy. This committee shall choose the name which it deems most suitable, observing the established Code of Nomenclature.
 - E. Existing American varietal names which conflict with earlier published foreign names for the same or different varieties but which have been thoroughly established through long usage shall not be displaced unless long-used and available synonyms exist.
 - F. It is recognized that certain strains of varieties may occur which do not differ from a standard variety in recognizable characters, but may differ in yield, adaptation, or quality and are entitled to recognition by a distinct name. Such strain shall be given a new name, but the name of the type variety in parentheses should follow.
3. **FORM OF NAMES.**—The name of a variety shall consist of a single word, except where it conflicts with rule 2, C or E.
 - A. Varietal names shall be short, simple, distinctive, and easily spelled and pronounced.
 - B. A varietal name derived from a personal or geographical name should be spelled and pronounced in accordance with the rules governing in the case of the original name.
 - C. The name borne by an imported foreign variety should be retained, subject only to such a modification as is necessary to conform it to this code.
 - D. The name of a person should not be used as a varietal name during his lifetime. The name of a deceased person should not be so used except by the official action of this or other competent agronomic bodies. Personal names in the possessive form are inadmissible.
 - E. Names of stations, States, or countries, in either the nounal or adjective form, should not be used as varietal names, except in unusual cases where the name is well established.

3. FORM OF NAMES—Continued.

- F. Such general terms as hybrid, selection, seedling, etc., should not be used as varietal names.
- G. A number, either alone or attached to a word, should not be used as a varietal name, but considered as a temporary designation while the variety is undergoing preliminary testing.
- H. Names which palpably exaggerate the merits of a variety shall be inadmissible.
- I. In applying the provisions of this rule to varietal names which have become firmly established in agronomic literature through long usage, no change shall be made which will involve loss of identity.

4. PUBLICATION.—A varietal name is established by publication. Publication consists (1) in the distribution of a printed description of the variety named, giving its distinguishing characters; or (2) in the publication of a new name for a variety properly described elsewhere, such publication to be made in any book, bulletin, circular, report, trade catalogue, or periodical, provided the same bears the date of issue and is distributed generally among agronomists and crop growers; or (3) in certain cases the general recognition of the name for a commercial variety in a community for a number of years may be held to constitute publication.

- A. Where two or more admissible names are given to the same variety, in the same publication, that which stands first shall have precedence.

5. REGISTRATION.—After a classification is made, and names assigned according to the code, and the same has been officially adopted by this society, no new names shall be recognized by the society except by registration. Registration shall consist in the introducer submitting to the secretary of the American Society of Agronomy, or some properly authorized committee a sample of seed, together with a full statement and evidence setting forth reasons why the variety is entitled to a new name. The society (or committee) shall then have sufficient time in which to grow the crop in trial grounds and thoroughly examine the claims before reporting on the new name.

6. CITATION.—In the full and formal citation of a varietal name, the name of the author who first published it shall be given when the same can be determined.

7. REVISION.—No properly published varietal name shall be changed for any reason except conflict with this code, nor shall another variety be substituted for that originally described thereunder.

NEW VARIETIES NAMED.

Since the adoption of this code names have been given to several new American varieties. They are Ashland, Forward, Honor, Kota, Laramie, Minhardi, Minturki, Norka, and Ruddy.

VARIETAL NAMES CHANGED.

Some changes in the nomenclature of wheat varieties already have been made, in accordance with the rules of the code. Principal among these are Preston for Velvet Chaff, Converse for one Red Russian, and Ladoga for Spring Turkey. In this bulletin the following changes are made: Satisfaction for Smith Rust Proof, Prosperity for American Bronze, Alton for Ghirka Winter, Dixon for

Humpback II, Emerald for Early Spring, Pentad for D-5, and Vernal for White Spring emmer. Of these, the first two are selections of existing synonyms that have been long used. The third and fourth are new names adopted because of the confusion existing in American literature between the varieties formerly called Ghirka Winter and Ghirka Spring and between Humpback and Humpback II, or Smooth Humpback. The fifth and seventh are new names selected for varieties formerly known only under the designation of a descriptive adjective, and the sixth is a name selected for a variety formerly known only by a letter and number combined.

The revision of varietal names is undertaken in this classification. The code provides that, if desirable, revision should be done, but without losing the identity of the name to the variety. Revision is absolutely necessary in some cases in order to avoid duplication of names and confusion and in other cases is desirable to simplify and standardize the nomenclature. These are important objects of the classification. Some revisions have already been made and the identity of the varietal name retained. Examples of this are Turkey for Turkey Red and Peliss for Pelissier.

The following simplifications of the names of wheat varieties are made in this classification. The rules of the code have been followed in all instances. In some cases the simplified name is not as satisfactory as might be desired, but undoubtedly it is an improvement. Several undesirable names of recognized varieties have not been revised, because it does not appear practicable at the present time, as they have about gone out of cultivation or are of little commercial importance.

List of simplified names used in this classification.

New name.	Original name.
Martin.....	Martin Amber.
Challenge.....	Webb's Challenge White.
Dart.....	Dart's Imperial.
Surprise.....	Pringle's Surprise.
Lynn.....	Lynn Rust Proof.
Pilcrow.....	Pilcrow Enormous.
Leap.....	Leap's Prolific.
Oakley.....	Extra Early Oakley.
Wyandotte.....	Wyandotte Red.
Purplestraw.....	Purple Straw.
Wellman.....	Wellman's Fife.
Ghirka.....	Ghirka Spring.
Climax.....	Jones Climax.
Dawson.....	Dawson Golden Chaff.
Arcadian.....	Early Arcadian.
Goldcoin.....	Gold Coin.
Allen.....	Red Allen.
Peterson.....	Lars Peterson.
Rupert.....	Rupert's Giant.
Currell.....	Currell's Prolific.
Red Clawson.....	Early Red Clawson.
Rochester.....	Rochester Red.
Red Chief.....	Early Red Chief.
Schlanstedt.....	Rimpau's Red Schlanstedter Sommerweizen.

List of simplified names used in this classification—Continued.

New name.	Original name.
Resaca-----	Red Resaca.
Silvercoin-----	Silver Coin.
Jones Fife-----	Jones Winter Fife.
Grandprize-----	St. Louis Grand Prize.
Mammoth Amber-----	Jones Mammoth Amber.
Palisade-----	White Palisade.
Baart-----	Early Baart.
Sibley-----	Sibley New Golden.
Champlain-----	Pringle's Champlain.
Java-----	Early Java.
Hussar-----	Red Hussar.
Blackhull-----	Clark's Black Hulled.
Gluten-----	Gluten B 86.
Silversheaf-----	Jones Silver Sheaf Longberry Red.
Link-----	Missing Link.
Genesee Giant-----	Early Genesee Giant.
Read-----	Read's Vermont Winter.
Longberry No. 1-----	Jones Longberry No. 1.
Penquite-----	Penquite's Velvet Chaff.
Jenkin-----	Jenkin's Club.
Redchaff-----	Red Chaff Club.
Wilbur-----	Early Wilbur.
Bluechaff-----	Blue Chaff Calvert Club.
Dale-----	Dale Gloria.
Clackamas-----	Clackamas Wonder.

SYNONYMY OF VARIETIES.

Many varieties are known by several names. The names here used for the recognized varieties are the original names or the name now most commonly used or are the new or simplified names, as provided for by the code of nomenclature. All other names used for the varieties here described are considered synonyms.

THE WHEAT PLANT.

The different cultivated varieties of wheat vary greatly in their habit, form, and structure, but all are annual grasses. The principal parts are the roots, culms, leaves, and spikes. There are two sets of roots, the first or seminal or seed roots and the second or coronal roots, the latter arising from the crown of the stem. The culm is a hollow, jointed cylinder comprising three to six nodes and internodes. The upper internode of the culm, which bears the spike, is called the peduncle. The leaves are composed of the sheath, blade, ligule, and auricle. The spike is made up of the rachis and spikelets, the latter in turn comprising the rachillas, glumes, lemmas, paleas, and the sexual organs, or the three stamens, and the single ovary with its style and stigma. Each of these parts may show distinct characters in different varieties. Those characters that do not vary or are not readily observed are of little value in classification. The root characters, for example, which are not apparent, can not be conveniently used, and no attention has been given to them in this work. Other characters, such as those of the sheaths, ligules, and auricles, are not generally used because they show very slight differences in different varieties.

The keys and descriptions which are used here to distinguish and identify varieties are based on characters which show considerable variation and therefore are of value.

MORPHOLOGICAL CHARACTERS.

The following pages present in detail such morphological characters of the wheat plant as have been found in the present study to be of the most taxonomic value. The characters used to distinguish the different species, subspecies, and lesser groups in the genus *Triticum* are often of no higher rank than the characters used to distinguish the cultivated varieties.

In the preparation of the key certain primary characters have been used in a regular sequence. These characters are designated as major characters, and in the key they are printed in capitals. Certain other characters are used in the key to separate further the closely related varieties. For this purpose any character is used which serves to distinguish the varieties under discussion. The same characters may not be used in two successive cases and they are not used in any definite order. These secondary characters are printed in ordinary type and are designated as minor characters. The general principle followed in the choice of characters in the key was to progress from those most easily observed and most often occurring to those least easily observed or least often occurring. The principle governing the sequence of characters in the key is to progress from the absence of the character, as awnlessness, to the presence of the character and from the smaller size to the greater.

The descriptions of the wheat varieties are arranged in a logical order of plant development. The major and minor characters used in the key are included in their proper places in the descriptions, as are many minor characters not used in the keys.

All of the taxonomic characters which are used in the keys and descriptions of cultivated varieties are considered below in the order of their appearance in the descriptions.

PLANT CHARACTERS.

Certain plant factors which are genetically different in the several varieties are of value for classification purposes. These are the habit of growth, the period of growth, and the height of the plant.

HABIT OF GROWTH.

All wheat varieties are here classified as having winter habit or spring habit of growth. These characters are shown in Plate II. In the keys to the cultivated varieties they occupy the seventh and last major position. Varro (in Columella, 74) writing before

the beginning of the Christian era called the spring wheats *trimestrian*, because they matured in three months from sowing. Linné (140) treated them as separate species in his *Species Plantarum*, but combined the awned factor with the spring habit in his species *aestivum* and the winter habit with the awnless factor in his species *hybernum*. Few writers have since recognized these species, but the placing of both spring and winter forms of common wheat in one species, *Triticum vulgare*, by Villars in 1787 (198) has been almost universally accepted. The existence of winter and spring forms has been recognized by most authors but has not recently been used as a character for separating species or even as an important character for separating varieties. The writers consider these distinctions to be of less value for classification purposes than several spike and kernel characters, when the whole country is considered, although it is a very important separation in some areas. In the southern United States, both in the east and west, several varieties of spring wheat are fall sown, and growers do not know whether they have a spring wheat or a fall wheat. The Purplestraw variety of the Southeastern States has a true spring habit, although it has been grown from fall sowing in that section for more than 100 years. Nearly all of the varieties grown in Arizona and California are spring wheats, but are fall sown.

Hunt (123, p. 54) and others have pointed out that winter and spring wheats can be changed from one form to the other. These are factors which limit the value of the characters in classification. To use the winter and spring habit as the first separating characters also would widely separate otherwise very closely related varieties and in practice would result in a double classification.

The winter and spring habits are shown as the first characters in the descriptions, as those characters are the first apparent in the growth of the plant. In the key the wheats having a winter habit are listed before those having a spring habit, because there are more fall wheats than spring wheats and because fall wheat is of much greater importance in this country than spring wheat.

A few varieties of winter wheat are somewhat intermediate or facultative in their habit of growth. This is mentioned in the descriptions of such varieties, but in the key only the two classes are recognized. The intermediate types retain their prostrate habit of growth for only a short time or else they are semierect instead of prostrate. Early varieties of winter wheat have a short prostrate or dormant period, and when spring sown they begin heading only a few weeks after the spring wheats have headed, thus giving an appearance of intermediate habit at the later stages of growth. There are

also certain varieties of wheat which are not homozygous as to winter or spring habit. The habit of growth is determined by sowing the wheat in the spring and observing its behavior. A winter wheat is one which usually produces no seed when sown at the normal date of seeding for spring wheat. All varieties classed as winter wheats in the key can be successfully produced only from fall sowing. When spring sown they usually remain prostrate on the ground throughout the growing season and produce no culms or spikes. In some sections, or in some years, or when sown very early, winter-wheat varieties when spring sown will head and produce seed, but this usually occurs very late in the season.

All varieties of wheat classified as spring wheats can be successfully grown from fall sowing only in mild climates, such as the southern parts of the United States and along the Pacific coast. In parts of this territory they will sometimes winterkill. When spring sown their early growth is erect and culms and spikes are produced during the early part of the growing season.

TIME OF MATURITY.

The time between emergence and maturity is often an important economic factor in wheat production. The duration of the growing period is indicated by classing varieties as early or midseason or late. These are considered secondary characters, but nevertheless are important economically and also in classification. Winter wheats and spring wheats require periods for growth which can not be directly compared in number of days. Fall-sown spring wheats may mature as late as or later than many of the true winter wheats. The above separation, however, into three classes can be used for both fall and spring wheats, or for all wheats when sown in the fall. No definite unit of time is used, therefore, in defining these separations. It is simply a relative measurement to be used in comparing varieties with those of which the normal time of maturity is known. Spring varieties grown in the northern Great Plains area would be classified as early when maturing in 85 to 95 days after emergence, as mid-season when maturing in 90 to 100 days, and as late when maturing in 95 to 105 days. These variations are so small and such differences between the varieties are apparent during so short a period that these factors are of minor value in classification and are used only to separate closely related varieties.

TILLERING.

The tillering or stooling of wheat also is of little taxonomic value in separating varieties. Koernicke and Werner (133) recorded the number of plants and culms obtained from definite quantities of seed.

Grantham (98) showed that tillering is a varietal characteristic to a limited extent. He also showed that—

Since the number of tillers a wheat plant produces is dependent upon so many environmental conditions a number of observations must be made in order to establish in which degree this tendency is exhibited. For this reason it is difficult to classify varieties closely as to their tillering habit.

The degree of tillering, therefore, is of little value for classification purposes and is not used in the descriptions. A few varieties, such as Turkey, usually have a large number of culms per plant, while durum varieties have comparatively few.

HEIGHT OF THE PLANT.

The height of the plant also is often an important economic factor in wheat production, because it may determine the method or ease of harvesting. Height is measured from the surface of the ground to the tip of the spike, not including the awns of awned varieties. In regard to height, all varieties of wheat have been placed in the three classes—short, midtall, and tall. These are characters of minor value for classification and are used only for separating or distinguishing otherwise closely related varieties. The principles governing the grouping of varieties as early, midseason, and late apply here also. As an example, under California conditions wheats from 12 to 36 inches in height would be classed as short; wheats from 24 to 48 inches in height would be called midtall, and wheats from 36 to 60 inches high would be considered tall. In most other sections of the country these differences would not be as great. In order to use the height of the plant as a character, the height of certain varieties must be determined and used for comparison.

STEM CHARACTERS.

There are three characters in the stem of wheat varieties which are useful in classification, namely, height, color, and strength. Height already has been considered as a plant character.

COLOR OF THE STEM.

All varieties of wheat are here classified as having white or purple stems. The colors of the stem and the variations that exist are shown in Plate III, Figure 1, *a* and *b*. These characters are of minor importance in classification, for in many localities and in some seasons the purple color common to a large number of wheat varieties does not become apparent. This often is the case under conditions of extreme drought and also under conditions of excessive moisture. Under favorable conditions, however, this stem color is very apparent during a week or 10 days in the ripening period. When apparent, the color differences are very useful in distinguishing varieties. The



WHEAT STEMS AND GLUMES.

FIG. 1.—Portions of wheat stems showing color, (a) white, (b) purple; and awns showing colors, (c) white, (d) yellowish, (e) brown, (f) black. FIG. 2.—Glumes of wheat varieties showing the colors, (a) and (b) different shades of white, (c) white with black-striped margins, (d) yellowish, (e) and (f) different shades of brown, (g) bluish brown, (h) black. (Enlarged 3 diameters.)

color is usually most apparent on the peduncle, or uppermost internode supporting the spikes, but often continues downward to the sheaths of the lower leaves.

Those varieties here described as having white stems may have a stem color ranging from a cream to a golden yellow. Few, if any, have stems which are truly white or with an absence of color.

The varieties classed as having purple stems may have a stem ranging in color from a pale violet to a dark purple. In some varieties this coloring may occur only in a short portion of the peduncle. It sometimes does not occur in the peduncle and is present only in the sheaths. As previously stated, under some conditions it may not appear at all in a variety where it normally is present. The exact cause and nature of this coloring have not been worked out by the writers. It is probable that different quantities of moisture, heat, and light influence the color development. Koernicke and Werner used color differences in describing many of the varieties with which they worked. Heuzé (112, p. 54) pointed out the two contrasting characters, which he called white and reddish. Color always has been considered of minor importance in classification, however.

STRENGTH OF THE STEM.

The strength of the stem usually is an important economic factor. In many localities it is one of the most serious problems in wheat production, as many varieties are likely to lodge under conditions of excessive moisture. All varieties here discussed are classified into three groups, having weak, midstrong, or strong stems, respectively.

Stems classed as weak are also usually slender, with very thin walls. Varieties with such stems have a greater tendency to lodge, which in turn causes harvest losses and increases the cost of harvesting. The successful cultivation of weak-stemmed varieties usually is limited to semiarid or arid regions.

The varieties classed as having midstrong stems will not lodge under conditions favorable for wheat production. In this class are included the greater number of American varieties. A considerable variation exists within this group, and in humid sections varieties here described as having midstrong stems might more properly be classed as weak. In arid sections certain of these stems might more properly be classed as strong.

The varieties here described as having strong stems are those that will not lodge readily under excessively humid conditions. Only by a severe rain, hail, or wind storm can the stems of these varieties be bent or broken down. Comparatively few of the cultivated American wheats come in this class. Of these, the club wheats are of most importance.

LEAF CHARACTERS.

The principal parts of the leaves of wheat plants are the sheath, blade, ligule, and auricle. None of these parts usually show differences which are of even minor value for distinguishing cultivated varieties.

The blades of wheat varieties vary considerably in their dimensions, in the shade of green color, and in the angle to the culm maintained during the successive periods of plant growth. These differences, however, are apparent during only a short period. As the plant matures, the blades dry and frequently break off. Practically all cultivated varieties normally have three leaves, although this sometimes varies under unfavorable or very favorable conditions. In this bulletin very little use is made of leaf characters. A few varieties are noted as having especially broad or narrow blades or as being pubescent.

Koernicke and Werner (1933) and others have described the color of the blades of both the seedlings and the partly grown plants. This also was attempted in the present studies, but the differences were found to be so slight and undependable that no definite classes could be established by using the character. No two persons can agree as to the various shades of green shown by the blades of wheat, even when a standard color chart is used. The color varies with the condition of the plant as affected by the temperature, the soil moisture, and the soil solution. The appearance of the color is changed by the character of the venation and of the blade surface. The plants appear to have a different color in the sunlight than in the shade, and the value changes also according to the position of the observer with regard to the direction of the rays of the sun. In general, the Crimean wheats have dark-green blades, while all durum varieties have blades with a light-green color.

The blade widths are mentioned in describing only a few varieties, because nearly all varieties are very much alike in this character. The Crimean wheats are distinctly narrow leaved, while varieties like Sol and Red Russian have wide leaf blades. In America the winter varieties having the narrowest blades usually are most winter hardy. The length of the blade has not shown sufficient constant differences for taxonomic purposes.

The terminal leaf of different varieties of wheat is sometimes quite erect and sometimes drooping at various angles. These differences are greatest just previous to the heading period, but frequently are not apparent a few days later. Chiefly because of the instability of this character, it is not used in this classification.

The sheaths normally inclose about the lower two-thirds of the culm, although in dry seasons the spike sometimes is not entirely

exserted. The edges of the sheath overlap on the side opposite the blade. The sheaths may be either white or purple. During early growth they usually are quite scabrous, but become smoother at maturity. There are some differences in these characters in the cultivated varieties, but they are few and minute. After a careful study the writers decided not to include any sheath characters in the descriptions.

The same decision was reached in regard to the minute differences observed in the ligules and auricles. The ligules usually are short, varying from 1 to 2 mm. long, and becoming lacerate as the plant matures. Auricles always are present on wheat leaves. They are narrow to midwide, usually strongly curved, with a few long strigose hairs on the outer margin. The auricles often are purple in the young stage, sometimes changing to white as the plant matures.

SPIKE CHARACTERS.

The entire inflorescence on one culm is called the spike. It is made up of separate groups of flowers known as spikelets. These are borne singly on alternate sides of a zigzag, flattened, channeled, jointed rachis, parallel to its flat surface. At the base of each spikelet, on the apex of each rachis joint, a tuft of short hairs usually occurs. These hairs may be white or brown in color, but the differences are difficult to distinguish, partly because the hairs frequently are discolored.

Spikes differ greatly in form and degree of compactness. Club wheats (*Triticum sativum compactum*) have been separated from common wheats (*T. s. vulgare*) principally because of their distinctly compact or dense spikes.

In distinguishing the cultivated varieties, four spike characters are used. These are the awns, the shape, the density, and the erectness of the spikes.

AWNS.

All varieties of wheat are classed here as awnless or awned. Spikes of awnless and awned varieties, showing some of the variations that exist, are shown in Plate IV. The awns are important agriculturally and usually are the character most readily apparent. For these reasons this character has been given precedence over all others in preparing the keys. Some early writers, as previously stated, used this character for separating so-called species.

Awnless varieties may have short or intermediate or no apical awns, that is, awns near the apex of the spike. Whether the awns are wanting or present, the varieties classed as awnless can be distinguished easily from varieties that are awned throughout. Apical awns on varieties classed as awnless occur only on few to several of the uppermost spikelets, except in a few varieties, and seldom, if ever,

exceed 5 cm. in length. From a genetic standpoint there probably are at least three distinct kinds of awnlessness. For the present classification, however, they are all classed as awnless, but in the descriptions the average extreme lengths of the apical awns are recorded.

Awned varieties are those that have an awn or beard which terminates the lemmas on all spikelets. These awns usually increase in length from the basal part of the spike upward. In the common wheats, awns seldom, if ever, exceed 10 cm. in length. In durum and poulard wheats, however, they usually range from 10 to 20 cm. in length.

SHAPE OF THE SPIKE.

Spikes differ greatly in shape, length, and width. They may be flattened parallel to or at right angles to the plane of the face of the spikelets. Those flattened parallel to this plane are widest when seen in face view and can be said to be dorsoventrally compressed. All varieties of common wheat have spikes thus formed, except those that are clubbed at the tip, in which case they are only partly so. Spikes that are flattened at right angles to the plane of the face of the spikelets are narrow when seen in face view and may be described as laterally compressed. The club, durum, and poulard wheats are separated from the common wheats partly on the basis of having such spikes.

In general, spikes vary in length from 5 to 15 cm., but are usually 8 to 12 cm. long. They vary in width or thickness from 1 to 3 cm. The differences in length and width are not used in themselves but are often combined with the spike shape in a compound descriptive word.

Whether dorsoventrally or laterally compressed, whether long or short, or narrow or wide, spikes are classified in the keys as having the following four general shapes—fusiform, oblong, clavate, and elliptical. These shapes are shown in Plate V. For all common wheats these shapes are determined from a face view of the spikelets and for all club, durum, and poulard wheats from an edge view of the spikelets.

Heuzé (112) used several different spike shapes as the leading characters in separating varieties within the species. The shapes mentioned, however, are here considered only as minor characters, though nevertheless very useful in distinguishing varieties.

Spikes classed as fusiform taper toward the apex or from the middle toward both base and apex. The larger number of varieties of common wheat have spikes of this shape.

Spikes described as oblong are usually quite uniform in width and thickness throughout the length of the spike, but are always several times longer than wide.

Varieties classed as having clavate spikes are clubbed, that is, distinctly larger and more dense at the apex. This is due to a shortening of the rachis internodes in that part of the spike, which results in a change from dorsoventral to lateral flattening and a broadening of the upper portion of the spike.

Elliptical spikes are short and quite uniformly rounded at both the base and apex, but are flattened on the sides. Most varieties of club wheat have spikes of this shape.

In the descriptions of varieties these designations of spike shapes have sometimes been modified to take into account the length and width of the spikes and the overlapping of shapes which occurs in some varieties.

Spikes that are unusually long are described as linear-fusiform, linear-clavate, etc. If spikes are unusually short that fact is included in the description. Broad spikes may be described as broadly fusiform or broadly oblong and narrow spikes as narrowly fusiform, etc.

Varieties that are nearly intermediate between any of the shapes are sometimes described as oblong-fusiform or oblong to subclavate. By the use of these compound descriptive terms spike shapes are more accurately presented in the description than they can be in the keys, where brevity is imperative.

DENSITY OF THE SPIKE.

The differences in shape of spikes shown above are due in part to differences in density. All spikes are described as of three density classes, viz, lax, middense, and dense. These differences are shown in Plate VI. These are minor differences which are used to advantage in distinguishing varieties. Seringe (174) separated the common wheats into two groups, having lax and dense spikes, respectively. Koernicke and Werner (133) described the spikes of many varieties according to different degrees of density. Neergaard (147) suggested a formula for use in measuring the density of the spike. Eriksson (88) subdivided the botanical groups of Koernicke and Werner on the basis of density into subvarieties called *laxum*, *densum*, and *capitatum*. He measured the density of spikes by determining the number of spikelets in 100 mm. of rachis length. Heuzé (112) used the spike density along with spike shape as the leading character in separating varieties. Boshnakian (48) described means of measuring density and suggested the name *Triticum compacto-capitatum* for varieties of club wheat having clavate heads.

Many measurements have been made by the writers to determine the difference in density of the spikes of the varieties here described. The most definite were found comparable at one station for one year, but otherwise were of little value. It was found necessary to estab-

lish density classes of rather indefinite limits. In this way allowance was made for the varying conditions. The density classes were finally fixed as lax, middense, and dense by determining the number of millimeters occupied by 10 internodes of the rachis measured in the center of the spikes. By this method spikes are classed as lax when 10 internodes occupy from 50 to 75 mm., as middense when 10 internodes occupy from 35 to 60 mm., and as dense when 10 internodes occupy from 20 to 45 mm. The greater number of varieties are included in the middense class, which, according to the above measurements, overlaps both the dense and lax classes by two-fifths of their entire range.

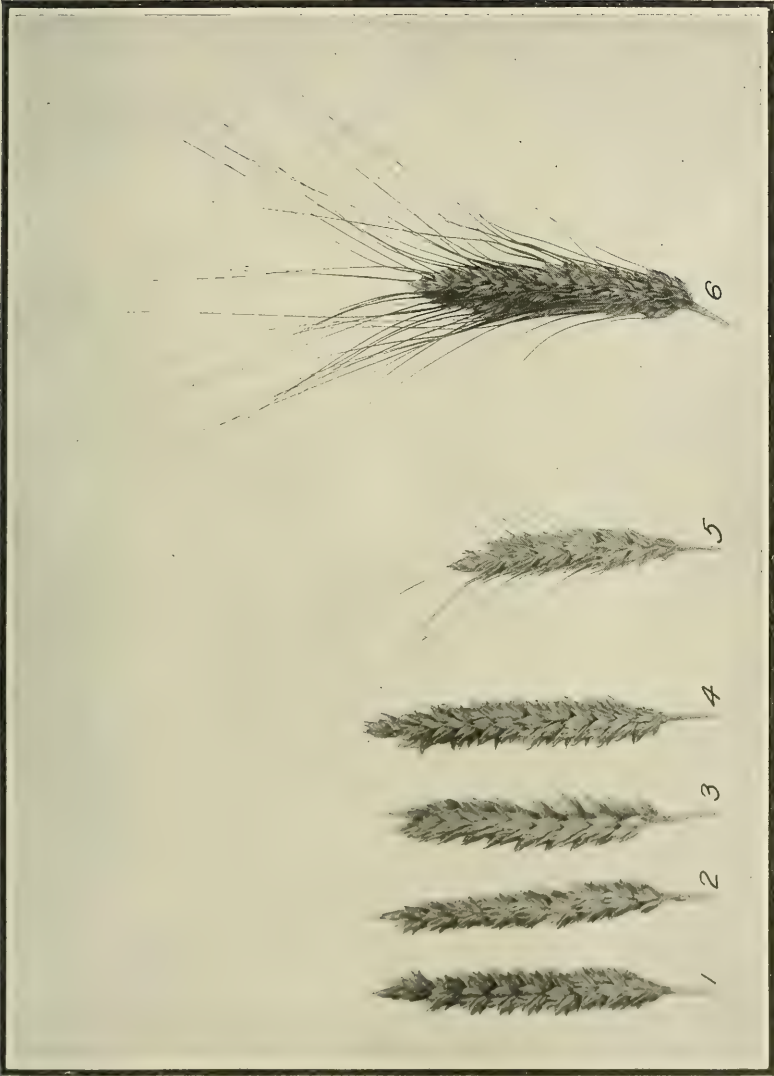
POSITION OF THE SPIKE.

The position of the spike at maturity is often distinctly different in different varieties. All spikes are here described as erect, inclined, or nodding. Heuzé (112) used essentially these same distinctions in describing his varieties.

Those varieties described as having erect spikes mature with the spike in an approximately vertical position. The spikes of these varieties seldom, if ever, are inclined more than 15 degrees from the vertical at maturity. Spikes of varieties which are described as inclined usually mature at an angle of approximately 15 to 45 degrees from the vertical, but sometimes are nearly erect, and under some conditions will become slightly nodding. The majority of wheat varieties come within this class. Varieties which are described as having nodding spikes usually mature with the spike in a drooping position, the apex of the spike being lower than the base. Spikes of such varieties sometimes are only inclined if they are not well filled with grain when ripe.

GLUME CHARACTERS.

The unit of the spike is the spikelet. It consists of several flowers or florets attached alternately to opposite sides of a central axis or rachilla. These flowers, three to five in number, are subtended by two empty scales, called the glumes, the keel of which terminates in a tooth or beak. Each floret consists of a flowering glume, called the lemma, and a thin 2-keeled glume called the palea. These two glumes inclose the sexual organs. The lemma incloses the back, dorsal, or outer portion, of the mature kernel and in the awned varieties terminates in an awn. The lemma itself is of little or no use in classification. The palea protects the inner or crease side of the kernel. It differs from the lemmas in having its back, instead of its face, toward the rachilla or axis of the spikelet. Like the lemmas, it is not used in distinguishing varieties. The glumes, however, are much used.



SPIKES OF AWNLESS AND AWNED VARIETIES OF WHEAT, SHOWING VARIATIONS IN LENGTH

Apical awns wanting, Bobs (1); apical awns few, White Fife (2); apical awns several, Satisfaction (3); apical awns many, Rink (4); awns midlong, Turkey (5); awns long, Kubanka (6).



SPIKE SHAPES OF WHEAT VARIETIES.

Fusiform, Ghirka (1), Rink (2); oblong, White Winter (3), Poole (4); clavate, Satisfaction (5), Arcadian (6); elliptical, Hybrid 128 (7).



SPIKE DENSITY OF WHEAT VARIETIES.

Lax, Chul (1), Martin (2); middense, Power (3), Regenerated Defiance (4); dense, Pacific Bluestem (5), Gypsum (6).

The covering and coloring of the glumes are major characters of the second and third place, respectively. The length and width of the glumes also are used, but are of only minor importance.

COVERING OF THE GLUMES.

Glumes of all varieties here discussed are described as glabrous or pubescent (Fig. 2). Host (119) placed the pubescent-glumed wheats in a separate species called *Triticum villosum*. Several later authors also considered pubescent wheats as different species. This character is used here, however, only as a major one in separating varieties, but is given the second place in the keys because of the definite and striking contrast between absence and presence. This action is in accordance with the usage of Koernicke and Werner.

Glumes described as glabrous are without any covering of hairs. Those described as pubescent are more or less covered with hairs of varying length. Pubescence usually is readily apparent. The degree of pubescence varies in the different varieties. On some the hairs are much longer and more numerous than on others. Glumes of some durum varieties are partly glabrous and partly pubescent, but are classed as pubescent. In such varieties the pubescence is most often found on the edge of the glumes.

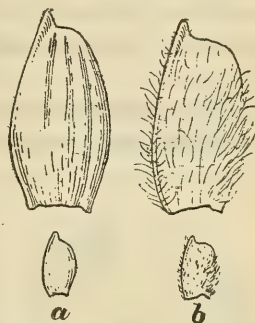


FIG. 2.—Glume covering: *a*, Glabrous; *b*, pubescent. (Natural size and enlarged 3 diameters.)

COLOR OF THE GLUMES.

Differences in glume color were early recognized. Lamarck (134) used these distinctions in classifying varieties. Glume color is here used as a major character and occupies third position in the key because of the distinct differences which are readily apparent when the plants are mature. This is also in accordance with the usage of Koernicke and Werner (133). All glumes are classed as white, yellowish, brown, or black. These colors are shown in Plate III, Figure 2.

Glumes classed as white may vary in color from a cream or pale-straw color to a dark yellow (Pl. III, Fig. 2, *a* and *b*). Practically no glumes are without color. Within the class, however, there are two rather distinct shades. Some taxonomists have classified them separately as white and yellowish. In the present bulletin, however, both shades are placed in the same class and described only by the one term "white," except in the case of the durum, which are classed separately as white and yellowish. In the descriptions the glumes of some varieties of common wheat are described as being yellowish

white, indicating a darker glume than those described as white. A few varieties have white or yellowish glumes with brown or black nerves, or the glumes are sometimes tinged on the edges with brown or black. Such varieties are placed in the white-glumed class and the peculiar markings are indicated in the descriptions. The Black-hull variety has glumes which usually are tinged with black, but sometimes are almost entirely black. The Rudy variety has black stripes along the edges of the glumes.

Glumes of durum varieties classed as yellowish are much darker than those of any of the common wheats classed as white or described as yellowish white (Pl. III, Fig. 2, *d*). This yellowish class, therefore, is quite distinct. It may range in color from a buff to bronze.

The brown-glumed class usually is still darker than this yellowish class and may vary in shade from light to dark brown and bluish brown, and in some varieties there is a reddish or mahogany tinge (Pl. III, Fig. 2, *e*, *f*, and *g*). For the latter reason most taxonomists have used the term "red," but in the present work the writers prefer the term "brown," as it more accurately describes the glume color of the class as a whole.



FIG. 3.—Glume length: *a*, Short; *b*, midlong; *c*, long. (Natural size and enlarged 3 diameters.)

Black-glumed wheats are rare in America. With two exceptions, and these only among the durum (Kahla, Pl. III, Fig. 2, *h*) and emmers (Black Winter), there are no commercial varieties having black glumes. The color of the glumes of these varieties

varies considerably. Under very dry conditions they may be only faintly tinged and may be more of a blue than a black.

LENGTH OF THE GLUMES.

Glume lengths are described as short, midlong, and long and are used as minor characters in the varietal descriptions. These length differences are illustrated in Figure 3. Usually small-kerneled varieties have short glumes and large-kerneled varieties long glumes, but there are exceptions to this. The glumes are usually about three-fourths the length of the lemmas, although in some long-glumed varieties the glumes and lemmas more nearly approach the same length. Polish wheat, *Triticum polonicum*, has glumes as long or

longer than the lemmas and is separated from the other species principally on this distinction. The length of the glume is here described as short, midlong, or long. Heuzé (112) and Scofield (173) used essentially these same terms. Most varieties of wheat have midlong glumes. A few varieties, however, are distinct in having either short or long glumes. Short glumes may have lengths varying from 6 to 10 mm. Midlong glumes may vary from 8.5 to 12.5 mm., and long glumes from 11 to 15 mm. The glumes of Polish wheat exceed this latter measurement and are described as very long.

WIDTH OF THE GLUMES.

The width of glumes is used in the same manner as the length. All glumes are described as being narrow, midwide, or wide (Fig. 4). These differences were pointed out by Scofield (173). The width of the glume is here determined across its center from the keel to the margin of the outer side. Narrow glumes may vary in width from 2 to 4 mm., midwide ones from 3 to 5 mm., and wide ones from 4 to 6 mm. The differences are small, and much overlapping of the classes is inescapable. Wide glumes nearly cover the lemma at the point of measurement, while narrow glumes usually cover less than a third of it.

TENACITY OF THE GLUMES.

Glumes of different varieties vary in tenacity or the firmness of attachment to the rachis. The glumes of most varieties, especially of the *durums* and clubs, are persistent. Some varieties of common wheat, however, have glumes which are easily deciduous, causing the spikes to shatter. This character is mentioned only for such varieties.

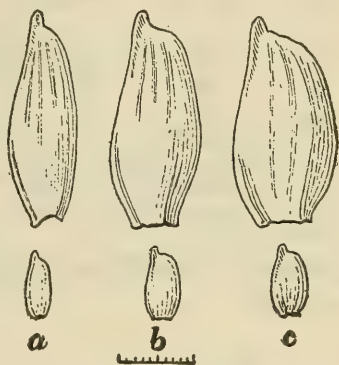


FIG. 4.—Glume widths: *a*, Narrow; *b*, midwide; *c*, wide. (Natural size and enlarged 3 diameters.)

SHOULDER CHARACTERS.

The shoulder as here considered is the more or less rounded end of the glume from the beak to the lateral margin, including the part referred to by Koernicke and Werner (133), Hackel (101), and others as side teeth. Scofield (173) applied the name shoulder to this portion of the glumes.

Considerable variation exists in shoulder width and shape in different varieties and also in different spikes of the same variety and even among the glumes on a single spike. Although variable, they are of considerable minor value in classification.

WIDTH OF THE SHOULDER.

The shoulder widths often differ from the glume widths. For this reason they are described separately, but on the same basis of measurement and by the use of the same terms, narrow, midwide, and wide (Fig. 5).

SHAPE OF THE SHOULDER.

Shoulder shapes are described in overlapping terms which allow for a considerable variation, which is nearly always present in the same spike. The terms used are wanting, oblique, rounded, square, elevated, and apiculate. These shapes are shown in Figure 6.

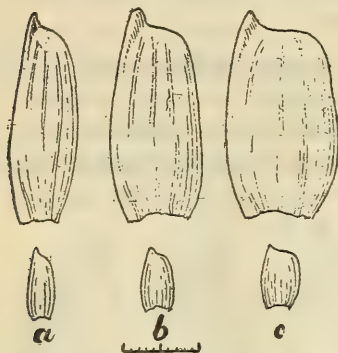


FIG. 5.—Shoulder widths: *a*, Narrow; *b*, midwide; *c*, wide. (Natural size and enlarged 3 diameters.)

importance in identification and are used in the descriptions of the varieties.

BEAK CHARACTERS.

The word “beak” is used here for the short projection which terminates the keel of the glume. In some varieties it approaches an awn in appearance. Scofield (173) first used the term beak, previous authors having referred to it as a tooth or point. The beaks vary in width, shape, and length. These characters are of considerable minor im-

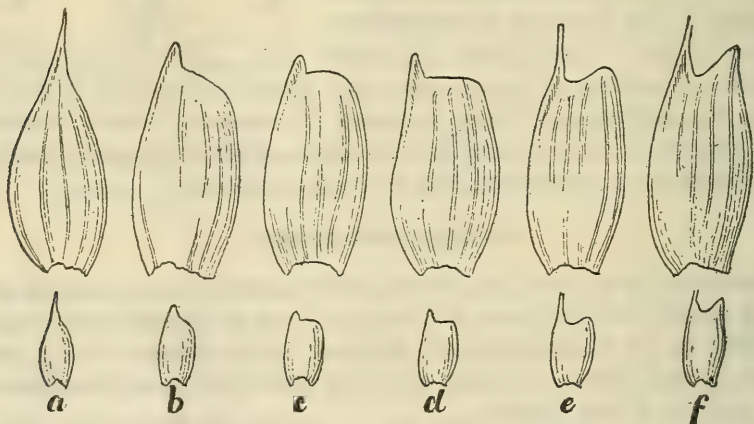


FIG. 6.—Shoulder shapes: *a*, Wanting; *b*, oblique; *c*, rounded; *d*, square; *e*, elevated; *f*, apiculate. (Natural size and enlarged 3 diameters.)

WIDTH OF THE BEAK.

Beak widths are described as narrow, midwide, and wide (Fig. 7). The average beak is only about 1 mm. wide, so the variations are very

small, and general observation is the only basis for describing them. Those that are wider than the average are called wide, and those that are narrower are called narrow.

SHAPE OF THE BEAK.

The apex of the beak varies considerably in shape. It is described as obtuse, acute, and acuminate. Obtuse beaks are blunt at the apex.

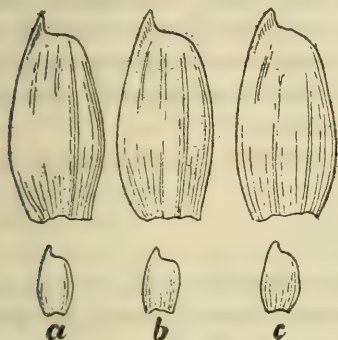


FIG. 7.—Beak widths: *a*, Narrow; *b*, midwide; *c*, wide. (Natural size and enlarged 3 diameters.)

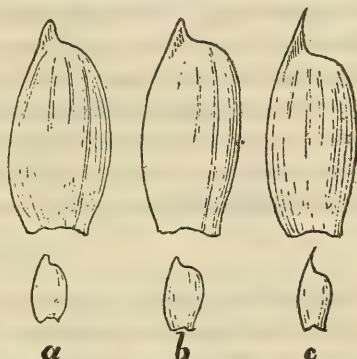


FIG. 8.—Beak shapes: *a*, Obtuse; *b*, acute; *c*, acuminate. (Natural size and enlarged 3 diameters.)

Acute beaks come to a point at the apex. Acuminate beaks are narrowly and very sharply pointed. All awned spikes have acuminate beaks. These shapes are shown in Figure 8.

LENGTH OF THE BEAK.

Beak lengths are quite variable, especially in the awned varieties, and are considerably influenced by environment. In general, conditions which increase or decrease the length of the beak affect nearly all varieties to a similar degree. In the awnless wheats the differences in length are not great, but in many varieties they are quite distinct. The length of the beak is measured from the shoulder of the glume upward. On most awned wheats the length increases from the base of the spike to its apex. The range of difference varies greatly with the variety.

For this reason no definite measurements are used in describing the lengths, but instead the average maximum and minimum lengths are recorded in millimeters. None of the awnless varieties here de-

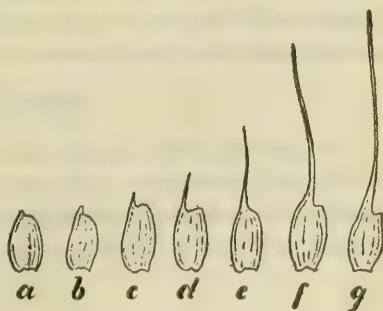


FIG. 9.—Beak lengths, showing seven variations. (Natural size.)

scribed have beaks longer than 3 mm. Variations in beak lengths are shown in Figure 9.

AWN CHARACTERS.

Certain characters of the awn are distinct. Some of these are of some importance in classification, while others are not. The divergence of the awn from the vertical is one of the latter. The awns of some varieties are all nearly vertical or appressed, while others are spreading. These characters are affected by drought or other abnormal conditions and usually are not sufficiently constant for classification purposes. The awns of some varieties sometimes are deciduous, dropping off at maturity. This occurs so rarely, however, that it is of little or no use in classification.

The color and length of the awns, however, are factors of some importance in this classification.

COLOR OF THE AWN.

In the key to the varieties of durum wheat the awn color is used as the fourth major character. This method was followed by Koernicke and Werner. For the other species and subspecies the awn color is used only as a minor character. All awns are described as white or black. The awn colors and variations in color are shown in Plate III, Figure 1, *c*, *d*, *e*, and *f*. The white class may include yellowish shades, and the black class may include shades of brown and blue. Few varieties of common wheat have really black awns.

LENGTH OF THE AWN.

The length of the awn in awned varieties or of the apical awns of varieties described as awnless is of slight value in classification. No attempt has been made in these studies to separate the varieties into classes with respect to awn length. In all descriptions, however, the average extreme lengths are recorded in centimeters.

KERNEL CHARACTERS.

The kernel color, length, and texture are the most constant of all the kernel characters. These are used as major distinctions. The shape of the kernel is considered only of minor importance, as are certain differences of the germ, crease, cheeks, and brush.

COLOR OF THE KERNELS.

Kernel colors were early recognized as important characters in separating varieties. Most varieties were observed to have either white or red kernels, but were sometimes regarded as being yellow or brown. The kernel color was used by Koernicke and Werner

(133) and by Vilmorin (199) as one of the leading taxonomic characters of wheat. Heuzé and Koernicke and Werner have indicated various shades of white or yellow and of red in the descriptions of the kernel color. Eriksson (88) believed that white wheat becomes red and states that the color of grain is useless in distinguishing a variety. Cobb (69) arranged the wheats he was growing according to the color tint from lightest to darkest. Howard and Howard (121, p. 288) regard the wheat kernel as being either white or red. They state that "the particular tone or color depends partly on the consistency of the grain." Hayes, Bailey, Arny, and Olson (105) proposed the use of the terms "red" and "white" in describing the presence and absence of a brownish red pigment in the bran layer. The use of the modification "light red" was suggested where the degree of pigmentation was less than usual in the red wheats. Three varieties of Abyssinian wheat having violet-colored kernels were mentioned by Koernicke and Werner (133). The writers have grown some purple-kerneled wheats from Abyssinia, but they are not considered in the present classification of the American varieties.

Kernels of all varieties are here grouped into two classes, described as white and red. Here, as in the glume colors, many different shades are present. In general, however, the two classes distinctly separate all wheats. Kernels showing the two colors and some of the variations that are found in normal and starchy samples are illustrated in Plate VII, Figure 1.

Kernels of the white class may vary from cream to yellowish, or they may be white, without pigment. White or faintly pigmented kernels may appear to have different shades of yellow color, because of differences in texture of the endosperm. Different textures of endosperm, ranging from starchiness to horniness, result in different color shades varying from white to yellow.

Kernels of the red class may vary from light brown to the darker shades of red. The variations are due to varietal differences and environment. Differences in texture, due to varying conditions, may cause "yellow berries," which sometimes gives the kernels a mottled appearance.

Many American writers have classed some varieties as "amber." This usually refers to a white kernel having a translucent or vitreous endosperm. The term "amber" is used to designate a certain subclass of durum wheat in the U. S. Official Grain Standards. Hard red kernels frequently have been referred to as amber colored. The word "amber" also has been used as a part of a varietal name, such as Martin Amber, which is a soft white wheat, and Michigan Amber, which is a soft red wheat. Because of this ambiguity and because all American wheats are either red or white, the word "amber" should not be used in describing wheat kernels.

LENGTH OF THE KERNEL.

The length of the kernel is used here as a major character in distinguishing varieties of common and club wheat.

Koernicke and Werner (133), in their descriptions of wheat varieties, indicated the average length and width of the kernels in millimeters and the average number of kernels in 10 grams. The kernels were described as very small, small, large, and long. Heuzé (112) described the kernels as short, medium, or long. The size of the kernels of any variety varies slightly when grown in different sections or in different years in the same section. From necessity, therefore, the limits of the classes in which varieties are placed must be

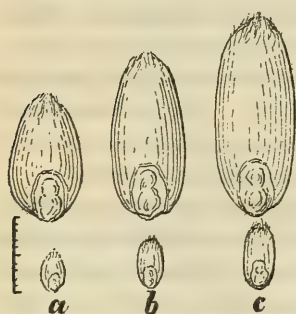


FIG. 10.—Kernel lengths: *a*, Short; *b*, midlong; *c*, long. (Natural size and enlarged 3 diameters.)

overlapping. A kernel of wheat reaches its maximum length several days before ripening. The length, therefore, is fairly constant, even when it is considerably shrunken, and is the most valuable of the kernel dimensions for taxonomic purposes. In making measurements only the normal kernels should be used. The kernels from the tip spikelets on a spike and from the upper florets in the spikelet are below normal in length.

In the keys two classes are made, namely, kernels short to midlong and kernels midlong to long. In the descriptions three classes—short, midlong, and long—sometimes are mentioned separately. These kernel lengths are shown in Figure 10.

The short to midlong class includes varieties whose kernels measure within the limits of 4 to 7.5 mm. in length. The midlong to long class includes varieties whose kernels come within the limits of 6.5 to 10 mm. For individual samples more definite limitation is possible. For this purpose the term "short" is used for kernels varying from 4 to 6 mm. in length; "midlong" for those varying from 6 to 8 mm., and "long" for those varying from 8 to 10 mm. These latter measurements are considered as minor characters and are occasionally used in descriptions either alone or usually following the adjective. The measurements, enlarged ten times, are illustrated in Figure 11.

TEXTURE OF THE KERNEL.

The texture of wheat kernels is an important character in classification. It has an economic value in America, as most wheat is marketed in commercial classes, which are fixed largely on a basis of texture, because hard wheats generally are better for milling and bread making than soft wheats.



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KERNELS AND CROSS SECTIONS OF WHEAT KERNELS.

Fig. 1.—Kernels of wheat varieties showing the colors: (a) White, 1, Goldcoin; 2, Baart; 3, Kubanka; (b) red, 1, Fultz; 2, Turkey; 3, Pentad. The lower row shows "yellow-berry" kernels of these varieties. (Enlarged 3 diameters.) FIG. 2.—Cross sections of wheat kernels of varieties having different textures: Soft, (1) Kofod, (2) Zimmerinan; semihard, (3) Jones Fife, (4) Champlain; hard, (5) Marquis, (6) Kubanka; 1, 2, and 3 are classed as soft to semihard, and 4, 5, and 6 as semihard to hard. (Enlarged 3 diameters.)

The texture classes used here are two—kernels soft to semihard and kernels semihard to hard. Here, as with size, overlapping class limits were found to be necessary. In general, all wheat varieties can be classed readily in one or the other of these two groupings. In describing specific samples and in individual description of varieties, three classes are used separately, as soft, semihard, and hard. A soft wheat is one which, when normally developed, has an endosperm entirely soft, mealy, or starchy. A hard kernel, when normally developed, has a corneous, horny, or vitreous endosperm throughout. A semihard kernel has an endosperm which is intermediate between the two. Cross sections of kernels showing differences in texture in both normal and yellow-berry kernels are shown in Plate VII, Figure 2. The upper series of kernels shows normal development and the lower series the yellow-berry condition. In Figure 2 *a*, (1) and (2) represent different degrees of softness and (3) the semihard con-

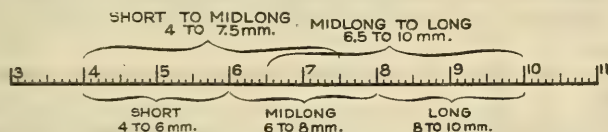


FIG. 11.—Diagram showing measurements of kernel lengths: Above, major characters; below, minor characters. (Enlarged 10 diameters.)

dition in the soft class. In Figure 2, *b*, (4) shows the semihard condition and (5) and (6) different degrees of hardness.

The species *Triticum durum* was so named by Desfontaines (79) because of the hardness of the kernels. Metzger (143) divided the white-kerneled wheats into two groups on the basis of texture, the starchy ones being considered as yellow. Koernicke and Werner (133) described the wheat kernels of different varieties as being entirely mealy, nearly entirely mealy, mostly mealy, partly mealy, partly glassy, mostly glassy, nearly entirely glassy, and entirely glassy. The texture of the same variety varied in different seasons. These authors, as well as Eriksson (88), Fruwirth (92), and Howard and Howard (121, p. 232), conclude that kernel texture is useless as a varietal character and that it depends on environment. Hayes, Bailey, Arny, and Olson (105) suggest the terms corneous, subcorneous, substarchy, and starchy for describing the texture of the wheat kernel. The writers have concluded that because of the variability in texture under different environments one can separate varieties of wheat accurately into only two classes and fairly accurately into three classes. Soft-kerneled varieties grown under very dry conditions will sometimes become brittle and slightly subcorneous. When hard-kerneled varieties are grown under humid conditions or in soil deficient in nitrogen they sometimes become starchy, semistarchy, or

mottled, the condition being designated as "yellow berry," and are then rather soft.

The difficulty of the numerous investigators in determining the kernel texture has been due to the failure to dissociate softness from starchiness or yellow berry. Freeman (91) has shown the nature of hardness in the wheat kernel. The following is quoted from his conclusions:

1. The hardness of a wheat is determined by the solidity of the grain, and this, in turn, by the nature and relative proportions of gluten and starch in the endosperm.

2. When the ratio of gluten to starch is sufficiently high, the entire cell contents are cemented together solidly as the grain dries out in ripening. It, therefore, takes on a hard, glassy, semitranslucent texture. In the absence of a sufficient proportion of gluten to hold the cell contents together, the shrinkage in drying does not fully compensate for the loss of water, and air spaces appear within the cells. These open spaces render the grain soft and, also, since they serve as refracting surfaces, make it opaque. We are, therefore, accustomed to associate softness, opaqueness, and low gluten content in wheats.

3. There are two types of soft grains among the wheats included in these experiments.

- (a) A type designated by the writer as "true softness," in which the air spaces in the endosperm are diffuse and finely scattered. This type of softness is only slightly affected by environic conditions.

- (b) A type commonly called "yellow berry," in which the air spaces within the endosperm occur in flakelike groups with quite definite margins. The opaqueness thus arising may be confined to a small spot only or may include the entire endosperm. This type of softness is very sensitive of environic conditions.

In this bulletin soft texture refers to the condition designated above as "true softness" and must not be confused with yellow berry.

True kernel texture, therefore, can not be determined on yellow-berry kernels, because they always are soft. It usually is possible, however, to select from a sample a few kernels which are not wholly starchy and which can be accurately used for texture determinations. Roberts (159) has attempted to measure hardness mechanically by determining the crushing strength. This is not entirely accurate, as the shape of the kernel influences its crushing strength and, in addition, soft-wheat varieties grown under dry-land conditions are quite brittle and difficult to crush. Texture is determined by cutting kernels which are not affected by yellow berry and examining the endosperm.

SHAPE OF THE KERNEL.

The shape of kernel outline is described as ovate, elliptical, or oval. These terms refer only to the outline of the kernel as viewed from the dorsal surface, and not to the kernel as a whole. When egg-shaped in outline, the germ end being the broader, it is described

as ovate. An elliptical kernel outline is one the length of which is more than twice the width and which has sides somewhat curved and both ends rounded. An oval kernel outline is broader, like the ovate, but with both ends of nearly equal width. The three shapes, ovate, elliptical, and oval, are shown in Figure 12, *a*, *b*, and *c*. Modifications of these shapes are indicated by describing kernels as narrowly or broadly elliptical, ovate, or oval, as the case may be. A few varieties, as Baart, show other characteristic shapes, which are given in the descriptions of these varieties.

Most kernels are classified as ovate, but in a few varieties a considerable portion of the kernels may have one or the other of the shapes just noted. The shape of the wheat kernel is influenced by the position in the spikelet, the position in the spike, and the degree of plumpness. Boshnakian (49) has shown that spikelet characters which affect the shape of the wheat kernel are mainly: "(1) The stiffness of the glumes, (2) the size and shape of the space in which the grain develops, (3) the number of grains in the spikelet and their position, (4) the density of the head, (5) the pressure caused by the growth of different parts of the head, and (6) the species which produces the kernel." The kernels from the base or tip spikelets on the spike are shorter in proportion to width than the others. The kernels from club wheat or from the tip spikelets of clavate spikes of common wheats are usually laterally compressed or "pinched." Shrunken kernels usually have an elliptical shape because of being narrow. As the width of a kernel of wheat depends largely upon the degree of development of plumpness, this character has very little taxonomic value.

The tip or brush end of nearly all varieties is rounded, but the kernels of a few varieties, in which the tips are square rather than rounded, as seen from the dorsal view, are described as truncate. Kernels of a few varieties have acute or pointed tips, as seen in both dorsal and lateral views, and such tips are described as acute.

The shape of the kernel as seen in the lateral view is important in only a few varieties. Many varieties, especially *durums* and *emmers*, are more or less keeled on the dorsal surface. Normally the kernels of wheat, in dorso-ventral diameter, are thickest near the base, just above the germ. In a few varieties the kernels are strongly elevated on the dorsal side of this basal portion and then are popularly known as "humped." That term is used in describing such kernels.

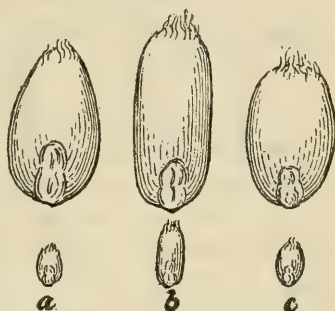


FIG. 12.—Kernel shapes: *a*, Ovate; *b*, elliptical; *c*, oval. (Natural size and enlarged 3 diameters.)

When the dorsal portion is less keeled than normal the kernel is described as flattened. Where only the tip of the kernel is thus flattened it is described as having a flattened tip.

The shape of the kernel has been used as a distinguishing character by only a few authors. Koernicke and Werner (133) recorded the lengths and widths of the kernels and referred to some as roundish or elongated. Eriksson (88) used the number of kernels in 100 mm., placed side by side, to indicate the width of the kernel. This character is, however, of value only in comparing varieties grown under identical conditions. Heuzé (112) described the shape of kernels of each variety, using such terms as elongated, short, angular, compressed, ovoid, oblong, and swollen. Scofield (173) suggested 16 descriptive terms to be applied to the shape of wheat kernels. Wheat kernels can not be accurately described according

to shape unless they are nearly normally developed, that is, neither shrunken nor excessively plump.

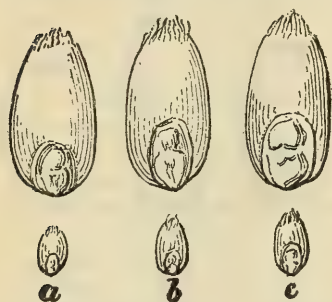


FIG. 13.—Germ sizes: *a*, Small; *b*, midsized; *c*, large. (Natural size and enlarged 3 diameters.)

GERM CHARACTERS.

The size and shape of the germ or embryo of the wheat kernel have seldom been used as characters in classification. After examining thousands of samples, the writers have concluded that the size of the germ is one of the most constant of minor kernel characters. There is considerable variation among the individual kernels of a bulk sample, but typical kernels of a pure variety have a characteristic size of germ. The germ is developed earlier than the endosperm and consequently is of almost normal size even in shrunken grain.

The germ is here described as small, midsized, or large. These are shown in Figure 13. A small germ is one which occupies less than one-sixth of the area of the dorsal surface of the kernel or the area visible in dorsal view. A midsized germ occupies from one-sixth to one-fourth of the dorsal area of the kernel. A large germ occupies one-fourth or more of the dorsal area.

The limits of the three size-groups overlap. Most kernels have a midsized germ, so these characters are not much used in distinguishing varieties. For some varieties, however, they could be used to advantage by men in the grain trade.

CREASE CHARACTERS.

The crease or sulcus on the ventral side of the wheat kernel is quite variable, but is of value in distinguishing a few varieties. The

chief taxonomic characters are the width and the depth. Shrunken kernels nearly always have a relatively wide and deep crease, while in extremely plump or yellow-berry kernels the crease is narrow and shallow because the space beneath the bran is occupied by large starch cells and air spaces.

WIDTH OF THE CREASE.

The width of the crease is determined by the distance between the crests of the cheeks on each side of the crease. Creases are described as narrow, midwide, and wide. These differences are illustrated in the cross sections of kernels shown in Figure 14. A narrow crease is about two-thirds or less of the total width of the kernel in ventral view. The midwide crease, which is typical of most varieties, is usually about four-fifths of the total kernel width. A wide crease is almost the total width of the kernel.

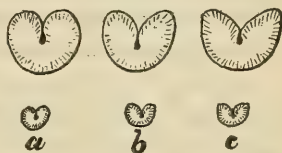


FIG. 14.—Crease widths: *a*, Narrow; *b*, midwide; *c*, wide. (Natural size and enlarged 3 diameters.)

DEPTH OF THE CREASE.

The depth of the crease in this classification has been determined by an external examination rather than by a cross section of the kernel. The depth, therefore, is measured from the crest of the cheeks to the position where the crease is closed. No measurements of the portion of the crease below the surface of the kernel have been considered. Crease depths are described as shallow, middeep, and deep. These differences are shown by cross sections of kernels in Figure 15. A shallow crease has a depth of 20 per cent or less of the dorsoventral thickness of the kernel. A middeep crease has a depth from 15 to 35 per cent of the thickness of the kernel, and a deep crease has a depth of 30 to 50 per cent of the thickness of the kernel.

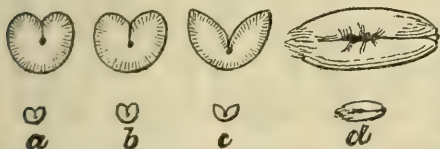


FIG. 15.—Crease depths: *a*, Shallow; *b*, middeep; *c*, deep; *d*, pitted. (Natural size and enlarged 3 diameters.)

The depth of the crease is of taxonomic value only when the kernels are normally developed and is a distinguishing character in only a few varieties. It

is sufficiently constant, however, to be of use in describing varieties grown under identical and normal conditions. Nearly all of the durum and club wheats have a shallow crease. A few varieties of common wheat have been described as having a "pitted" crease. This is characterized by having a distinct opening near the center of the crease (Fig. 15, *d*). The sides of the opening usually are wrinkled. The pitted character is most marked on the kernels of the Humpback and Huston varieties.

CHEEK CHARACTERS.

The cheeks of a kernel are the ridges along each side of the crease on the ventral surface of the kernel. The most distinguishing character of the cheek is the outline of the crest in cross section. This is described as rounded or angular. These shapes and some of the variations that exist in each are shown in Figure 16. Extremely

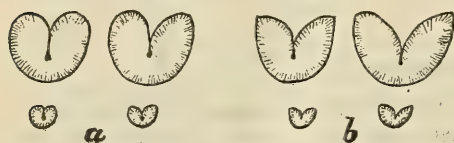


FIG. 16.—Cheek shapes: *a*, Rounded; *b*, angular. (Natural size and enlarged 3 diameters.)

starchy (yellow-berry) kernels always have rounded cheeks, while the cheeks of shrunk kernels are always angular. It is necessary, therefore, to examine normally developed kernels in order to recognize the differences. All of the durum wheats have angular cheeks. Most of the common wheats have cheeks which are more or less angular, but a few varieties, such as China and Turkey, consistently have rounded cheeks. There is no sharp distinction between the angular and the rounded cheeks.

BRUSH CHARACTERS.

The brush of the kernel is the hair at the tip or the end opposite the germ. Cobb (71) described in detail the brush of 50 varieties of wheat grown in Australia.

SIZE OF THE BRUSH.

The size of brush refers to the area which it occupies on the kernel. The area of the brush is described as small, mid-sized, and large. These differences are shown in Figure 17, *a*, *b*, and *c*. A small brush is one which occupies only a portion of the tip of the kernel. In kernels which are distinctly pointed at the tip, however, it may cover all of the end, but because of the small area occupied it is still referred to as small. A mid-sized brush covers the tip of the kernel. Nearly all varieties of wheat come within this class. A large brush is one which extends partly over the sides of the kernel, chiefly along the crease.

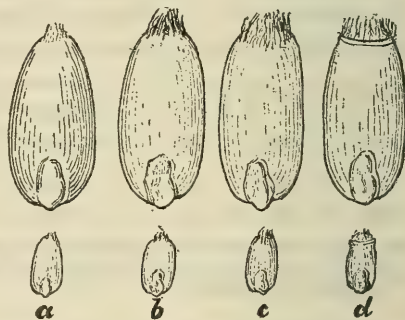


FIG. 17.—Brush sizes: *a*, Small; *b*, mid-sized; *c*, large; *d*, collared brush. (Natural size and enlarged 3 diameters.)

LENGTH OF THE BRUSH.

The length of brush refers to the average length of hairs, which are described as short, midlong, and long. These lengths are shown

in Figure 18. In short brush the hairs are less than 0.5 mm. long, in midlong brush from 0.5 to 1 mm. long, and in long brush more than 1 mm. long.

All durum wheats and some varieties of common wheat, such as Bobs and Prelude, have a short brush. A few very long hairs may be present in a short brush. Humpback and Mealy are varieties of common wheat having a long brush. Both the size and the length of the brush are very constant characters, probably the most constant kernel characters aside from color and size. In machine thrashing, part of the hairs of the brush frequently are removed. The brush area of some varieties is here described as "collared" (Fig. 17, *d*). Cobb (71) referred to this as an abrupt margin. This refers to the presence of a distinct raised collar or flange of bran along the margin of the brush area. This is most noticeable on shrunken kernels, but is very distinct on normal kernels of a few varieties, such as Goldcoin and Champlain.

PHYSIOLOGICAL CHARACTERS.

Several characters of wheat varieties of interest to growers can not be observed in a morphological examination. These differences are of a physiological or internal nature. They are of great economic importance, but are of little value in classification. Following the descriptions of many of the varieties, therefore, certain of the physiological characters here mentioned are considered.

The leading physiological characters of importance in wheat varieties are productivity, milling and bread-making values, resistance to low temperatures, and resistance to diseases.

PRODUCTIVITY.

A comparison of yield is of value only in comparing different varieties of wheat grown under identical conditions, as side by side, on identical soil, or in one locality in the same season. Under certain conditions it is possible for almost any variety to outyield all others, and consequently an expression of yield is of little taxonomic importance unless definite experiments at several points show a variety to be significantly high or low in yield. Koernicke and Werner (133) recorded the yields of the varieties grown at Poppelsdorf in the description of each variety. In the present work the writers have mentioned productivity or yield following the descriptions of only a few varieties, which experiments have shown to be distinctly high or low in yield.

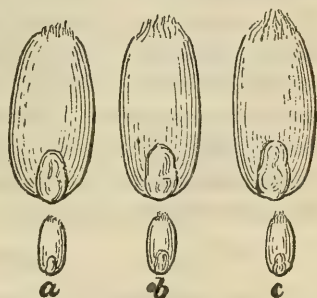


FIG. 18.—Brush length: *a*, Short; *b*, midlong; *c*, long. (Natural size and enlarged 3 diameters.)

MILLING AND BREAD MAKING.

Next to productivity, the value of wheat varieties for milling and bread making probably is of the greatest economic importance, as this is the principal use for wheat. There are significant differences in milling and bread-making values of different varieties. As in yield, these differences can be accurately determined only by careful experiments, identically conducted with comparable samples. Previous authors have not used these differences in distinguishing varieties. Where definite experiments have shown certain varieties to be unusually good or poor for milling or bread making, these differences are here pointed out, following the description.

RESISTANCE TO LOW TEMPERATURE.

Hardiness or resistance to low temperatures consists of both the ability to survive low winter temperature and resistance to injury from spring and summer frosts. Very little is known concerning the latter character. The winter hardiness of several varieties was recorded for three years by Eriksson (88) and the hardiness of many varieties was given by Koernicke and Werner (133). Following the descriptions here given, the writers have indicated a few varieties which are known to be especially winter hardy, but otherwise the character is not mentioned.

RESISTANCE TO DISEASES.

Wheat varieties are known which have more or less resistance to each of the various diseases of wheat. Practically all varieties of wheat have been grown in nurseries where they were infected either naturally or artificially, so as to be able to observe any marked resistance to stem rust (*Puccinia graminis*), leaf rust (*P. triticea*), stripe rust (*P. glumarum*), and bunt or stinking smut (*Tilletia tritici* and *T. foetens*). The presence of resistance can be determined only when all varieties have been equally exposed to all strains of a disease under conditions favorable for their development. A few varieties have shown a distinct resistance to stem rust or to bunt, and this fact is noted following their descriptions.

CLASSIFICATION OF THE GENUS TRITICUM.

Wheat belongs to the grass family, Poaceae (Gramineae), and to the tribe called Hordeae, in which the 1 to 8 flowered spikelets are sessile and alternate on opposite sides of the rachis, forming a true spike. Wheat is located in the subtribe Triticeae and in the genus Triticum, where the solitary 2 to many flowered spikelets are placed sidewise against the curved channeled joints of the rachis.

There are two sections of the genus Triticum, one including the old genus Aegilops, in which the glumes are flat or rounded on the

back, and the other including *Sitopyrus*, in which the glumes are sharply keeled and in which are found all cultivated forms. This bulletin is concerned only with the latter section of the genus *Triticum*.

There are many forms of einkorn, spelt, and emmer (including the so-called "wild wheat" of Palestine) which are not cultivated in the United States and, therefore, are not considered in these pages.

Wheat is characterized as a midtall annual grass with flat blades and a terminal spike. The spikelets are solitary, 1 to 5 flowered, sessile, arranged alternately on the nodes of a zigzag, channeled, articulate rachis; the rachilla of the spikelets disarticulating above the glumes and between the florets, or continuous; the glumes keeled, rigid, and 3 to several nerved, abruptly acute or acuminate; the lemmas keeled or rounded on the back, many nerved, ending in a single tooth or awn.

The following eight divisions of wheat varieties were used by Hackel (101, p. 180-187), and have been recognized by others:

Triticum...	sativum....	tenax.....	vulgare Vill.....	Common wheat.
			compactum Host...	Club wheat.
			turgidum L.....	Poulard wheat.
			durum Desf.....	Durum wheat.
		dicoccum Schr.....		Emmer.
	polonicum L.....	spelta L.....		Spelt.
				Polish wheat.
		monococcum L.....		Einkorn.

Only three of these divisions were considered by Hackel as valid and distinct species, namely, *sativum*, *polonicum*, and *monococcum*. The other divisions he called races and subraces. The term race is now more properly used for a pure line within a variety, and these ranks probably would be better designated as subspecies and varieties. As previously pointed out, other authors have considered these divisions as distinct species or subspecies. The present writers have not yet given sufficient study to the question of their botanical relationships to express a positive opinion.

In the present work it seems best to maintain these well-established divisions, but at the same time to rearrange their order. The writers make no attempt to assign definite rank to the different divisions, as they have not made a cytologic study of them or a genetic study of crosses between the different divisions nor have they made an exhaustive morphological study of existing varieties or strains which are of a type intermediate between any of the eight divisions. Such studies were not projected as a part of these investigations. The divisions which have been established or recognized as species or subspecies by different authors, however, may be distinguished by the accompanying key.

KEY TO THE SPECIES OR SUBSPECIES.

1a. Terminal spikelets fertile; palea remaining entire at maturity; spikelets with 2 to 5 fertile florets.	
2a. Glumes shorter than the lemmas, firm; palea as long as the lemmas. (<i>Triticum sativum</i> Lam.)	
3a. Rachis tenacious; kernels separating from the chaff when thrashed.	
4a. Glumes distinctly keeled only in the upper half; lemmas awnless or awns less than 10 cm. long; straw hollow.	
5a. Spikes usually long, dense to lax, somewhat dorsally compressed. (<i>T. aestivum</i> L., <i>T. vulgare</i> Vill.)	Page. COMMON WHEAT..... 50
5b. Spikes short, dense, laterally compressed. (<i>T. compactum</i> Host.)	CLUB WHEAT..... 172
4b. Glumes sharply keeled at the base; lemmas usually awned; awns 10 to 20 cm. long; straw usually solid.	
5a. Glumes and kernels short; kernels ovate, with truncate tips. (<i>T. turgidum</i> L.)	POULARD WHEAT..... 180
5b. Glumes and kernels longer; kernels usually elliptical. (<i>T. durum</i> Desf.)	DURUM WHEAT..... 183
3b. Rachis fragile; kernels inclosed in glumes when thrashed.	
4a. Spikes dense, laterally compressed; pedicel short, slender, usually attached to base of spikelet; shoulders wanting to narrow, usually oblique. (<i>T. dicoccum</i> Schrk.)	EMMER..... 193
4b. Spikes lax, narrow; pedicel long, wide, attached to face of spikelet below; shoulders wide, square. (<i>T. spelta</i> L.)	SPELT..... 195
2b. Glumes as long as or longer than the lemmas, papery, lanceolate; palea of lower flowers half as long as their lemmas. (<i>T. polonicum</i> L.)	POLISH WHEAT..... 197
1b. Terminal spikelets sterile, often scarcely visible; palea falling into two parts at maturity; spikelets usually with only one fertile floret.	
2a. (<i>T. monococcum</i> L.)	EINKORN..... 198

COMMON WHEAT.

In the Species Plantarum, Linné (140) first used the name *aestivum* for a part of the common and club wheats. This name originally referred to the awned spring forms. It has recently been used by some authors for the name of the subspecies commonly recognized as *Triticum sativum vulgare*. This name was applied to the common wheats by Villars in 1787, after it was pointed out that Linné's separations were not logical or correct. The name *vulgare* is usually preferred, because it means common, and has been almost universally accepted for more than 100 years.

Common wheat is distinguished from the other species or subspecies by a spike long in proportion to its thickness. The spike is usually dorsally compressed and is thus wide when seen in face view of the spikelets instead of narrow, as with those of some other divisions. The spikelets are 2 to 5 flowered, far apart, only slightly overlapping, pressed close to the rachis, and nearly erect. The glumes are keeled only in the upper half, shorter than the lemmas, firm, and either glabrous or pubescent. The lemmas are awnless or have awns less than 10 cm. long. The palea is as long as the lemmas and remains entire at maturity. The culm of the plant usually is

hollow, but occasionally is pithy within, and varies in strength and height. The blades of the leaves are usually narrower than those of the durum and poulard wheats. The kernels may be either soft or hard.

The greatest economic characteristic of common wheat is its well-known quality for bread making, as it excels all the other divisions in this important factor. It is also the best known and most widely cultivated of all the divisions and comprises more than four-fifths of the total number of varieties grown in the United States. More than 180 are distinguished by the following key. The varieties are most nearly related to the club wheats (*Triticum compactum*), but this separation of Host (119) is here used principally because of the greater density of the spike.

Common wheat is widely adapted to varying climatic conditions and possesses more diverse characteristics than any of the other divisions. The cultivated varieties are distinguished by the accompanying key.

KEY TO THE VARIETIES OF COMMON WHEAT.

1a. SPIKE AWNLESS.

2a. GLUMES GLABROUS.

3a. GLUMES WHITE

4a. KERNELS WHITE (*Triticum vulgare albidum* AL.)

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Spike fusiform.		Page.
Plant midtall; spike dense, erect.....	WINTER BLUESTEM.....	58
Plant tall; spike lax, nodding.....	MARTIN.....	58
Spike oblong.		
Spike erect.		
Keel straight above.		
Shoulders narrow, oblique to square.....	PROHIBITION.....	59
Shoulders wide, square to elevated.....	GREESON.....	60
Keel incurved above.		
Spike blunt at apex.....	WHITE WINTER.....	60
Spike tapering at apex.....	CHALLENGE.....	60
Spike sometimes slightly clavate.....	EATON.....	61
Spike inclined to nodding.....	WHITE WONDER.....	61
Spike clavate.....	SATISFACTION.....	61

SPRING HABIT.

Spike fusiform		
Plant early, short.		
Apical awns wanting.....	EARLY DEFIANCE.....	62
Apical awns several, 2-15 mm. long.....	COLORADO No. 50.....	62
Plant midseason, midtall.		
Apical awns wanting.....	TOUSE.....	62
Apical awns few, straight.....	DEFIANCE.....	63
Apical awns many, incurved.....	RINK.....	64
Spike oblong.		
Plant early, midtall.....	BUNYF.....	64
Plant midseason, tall.		
Glumes yellowish.....	PACIFIC BLUESTEM.....	65
Glumes bronze.....	MEXICAN BLUESTEM.....	66

1a. SPIKE AWNLESS—Continued.

2a. GLUMES GLABROUS—Continued.

3a. GLUMES WHITE—Continued.

4a. KERNELS WHITE—Continued.

KERNELS SHORT TO MIDLONG—Continued.

KERNELS SOFT TO SEMIHARD—Continued.

SPRING HABIT—Continued.

Spike clavate.

Plant early to midseason.

Spike erect.....	DART.....	Page.
Spike inclined.....	GYP SUM.....	66

Plant late.

Culm and spike only slightly glau-		
cous.....	SURPRISE.....	67

Culm and spike very glaucous.....	DICKLOW.....	68
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KERNELS SEMIHARD TO HARD.

SPRING HABIT.

Spike fusiform.

Plant early.

Apical awns wanting.....	BOBS.....	69
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Apical awns few, 3-5 mm. long.....	QUALITY.....	69
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Plant midseason.....	WHITE FIFE.....	70
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Spike oblong.

Plant early.....	WHITE FEDERATION.....	71
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Plant midseason; kernels mid-sized.....	LYNN.....	71
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Plant late; kernels small.....	REGENERATED DEFIANCE.....	72
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KERNELS MIDLONG TO LONG.

KERNELS SOFT TO SEMIHARD.

SPRING HABIT.

Spike oblong.

.....	NEW ZEALAND.....	72
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Spike clavate.....	PILCRAW.....	72
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4b. KERNELS RED (*T. v. lutescens* Al.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.

Spike fusiform.

Spike erect.

Plant early.....	RICE.....	73
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Plant midseason.....	MINHARDI.....	73
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Spike inclined.

Plant midseason.

Shoulders wanting to nar-		
row, oblique.....	LOFTHOUSE.....	74

Shoulders midwide, oblique		
to square.....	BIG FRAME.....	74

Plant late.....	BUFFUM NO. 17.....	75
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Spike nodding.

Plant early, midtall.....	LEAP.....	75
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Plant midseason, midtall.....	ONTARIO WONDER.....	76
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Spike oblong.

Spike erect to inclined.

Plant early, midtall.

Glumes midwide.....	ZIMMERMAN.....	76
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Glumes wide.....	WALKER.....	77
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Plant midseason, tall.....	HARVEST QUEEN.....	77
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Spike nodding; plant midseason,

midtall.

Apical awns straight.....	PROSPERITY.....	79
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Apical awns incurved.....	FORWARD.....	80
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Spike clavate.

Spike middense.....	SQUAREHEAD.....	80
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Spike dense.

Blades midlong, midwide.....	RED RUSSIAN.....	81
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Blades long, wide.....	SOL.....	81
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1a. SPIKE AWNLESS—Continued.

2a. GLUMES GLABROUS—Continued.

3a. GLUMES WHITE—Continued.

4b. KERNELS RED—Continued.

KERNELS SHORT TO MIDLONG—Continued.

KERNELS SOFT TO SEMIHARD—Continued.

WINTER HABIT—Continued.

Stem purple.

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Spike fusiform.....	
Spike erect.....	OAKLEY..... 82
Spike inclined to nodding.....	WYANDOTTE..... 82
Spike oblong.....	
Spike dense, erect.....	FLINT..... 82
Spike middense, erect to inclined.....	
Plant midtall.....	
Stem midstrong.....	FULTZ..... 83
Stem strong.....	ASHLAND..... 85
Plant tall, stem strong.....	TRUMBULL..... 85
Spike clavate.....	FULTZO-MEDITERRANEAN..... 85
SPRING HABIT.....	
Stem white; spike oblong, erect.....	KINNEY..... 87
Stem purple.....	
Spike fusiform, nodding.....	PURPLESTRAW..... 87
Spike oblong, erect.....	HUSTON..... 88

KERNELS SEMIHARD TO HARD.

WINTER HABIT.

Plant midseason.....	ALTON..... 89
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SPRING HABIT.

Stem white.

Spike fusiform.....	
Plant early, short to midtall.....	
Apical awns wanting.....	RED BOBS..... 89
Apical awns few, 1-10 mm. long.....	MARQUIS..... 90
Plant midseason, midtall to tall.....	
Spike dense, erect, short.....	RED FIFE..... 92
.....	POWER..... 93
Spike middense, inclined, mid-long.....	GLYNDON..... 93
.....	RYSTING..... 94
Spike lax, inclined, long.....	WELLMAN..... 94
Spike oblong, middense, erect; plant early, midtall.....	EARLY RED FIFE..... 95
Stem purple.....	
Spike fusiform; plant early.....	GHIRKA..... 95
Spike oblong.....	
Plant early, short.....	RUBY..... 96
Plant midseason, midtall.....	KITCHENER..... 96

KERNELS MIDLONG TO LONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.....	CLIMAX..... 97
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3b. GLUMES BROWN.

4a. KERNELS WHITE (*T. v. alborubrum* Kcke.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.

Spike fusiform.....	KOFOD..... 98
Spike oblong.....	
Spike inclined; kernels soft.....	DAWSON..... 98
.....	HONOR..... 99
Spike nodding; kernels semihard.....	SCHONACHER..... 99
Spike clavate.....	ARCADIAN..... 99
Stem purple.....	
Spike oblong, nodding.....	WINDSOR..... 100
Spike clavate, erect.....	GOLDCOIN..... 100

SPRING HABIT.

Spike fusiform.

Plant early.....	JOHN BROWN..... 102
Plant late.....	ALLEN..... 103

1a. SPIKE AWNLESS—Continued.

2a. GLUMES GLABROUS—Continued.

3b. GLUMES BROWN—Continued.

4a. KERNELS WHITE—Continued.

KERNELS SHORT TO MIDLONG—Continued.

KERNELS SOFT TO SEMIHARD—Continued.

SPRING HABIT—Continued.

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Spike oblong.....	FEDERATION..... 103
Spike clavate.....	FOISY..... 103

KERNELS SEMIHARD TO HARD.

SPRING HABIT.....	HARD FEDERATION..... 104
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4b. KERNELS RED (*T. v. mitura* Al.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.

Spike fusiform.

Plant early.....	GOLD DROP..... 105
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Plant midseason.

Spike inclined.....	HOMER..... 105
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Spike nodding.

Plant midtall.

Spike wide.....	RED WAVE..... 105
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Spike midwide.....	FLEMING..... 106
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Plant tall.....	PETERSON..... 106
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Plant late.....	ODESSA..... 107
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Spike oblong.

Spike erect to inclined.....	RUDDY..... 108
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Spike nodding.....	RUPERT..... 108
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Spike clavate.

Plant early, short.....	RURAL NEW YORKER No. 6. 109
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Plant late, midtall.....	SQUAREHEADS MASTER.... 110
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Stem purple.

Spike fusiform.

Plant early to midseason.

Spike inclined, narrow.....	CURRELL..... 110
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Spike nodding, wide.

Plant short.....	WINTER CHIEF..... 111
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Plant midtall.

Beaks 0.5 mm. long.

Stem midstrong.....	POOLE..... 113
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Stem strong.....	PORTAGE..... 113
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Beaks 1-1.5 mm. long.....	RUSSIAN RED..... 112
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Plant late, tall.....	CHINA..... 114
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Spike oblong, erect.

Shoulders wanting to narrow,

oblique.....	WHEEDLING..... 115
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Shoulders wide, square.

Plant midseason.....	RED MAY..... 115
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Plant late.....	ILLINI CHIEF..... 117
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Spike clavate.

Spike middense, inclined.....	RED CLAWSON..... 118
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Spike dense, erect.....	ROCHESTER..... 119
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RED CHIEF.....	119
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SPRING HABIT.

Stem white.....	SCHLANSTEDT..... 119
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Stem purple.....	RESACA..... 120
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KERNELS SEMIHARD TO HARD.

SPRING HABIT.

Stem white, spike fusiform.....	STANLEY..... 120
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2b. GLUMES PUBESCENT.

3a. GLUMES WHITE.

4a. KERNELS WHITE (*T. v. leucospermum* Keke.)

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Spike clavate.....	SILVERCOIN..... 120
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1a. SPIKES AWNLESS—Continued.

2b. GLUMES PUBESCENT—Continued.

3a. GLUMES WHITE—Continued.

4a. KERNELS WHITE—Continued.

KERNELS SHORT TO MIDLONG—Continued.

KERNELS SOFT TO SEMIHARD—Continued.

SPRING HABIT.

Spike oblong.	Page.
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Beaks 0.5 mm. long, obtuse.	JUMBUCK.	121
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Beaks 1-2 mm. long, acuminate.	INDIAN.	121
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4b. KERNELS RED (*T. v. villosum* Al.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Spike inclined; kernels semihard.

Germ small; cheeks rounding.	TRIPLET.	121
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Germ midlarge; cheeks angular.	MEALY.	122
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Spike nodding; kernels soft.	JONES FIFE.	123
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KERNELS SEMIHARD TO HARD.

SPRING HABIT.	HAYNES BLUESTEM.	124
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	DAKOTA.	126
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3b. GLUMES BROWN.

4a. KERNELS WHITE (*T. v. delfii* Kcke.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

SPRING HABIT.

Spike fusiform, beaks obtuse.	GALGALOS.	126
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Spike oblong, beaks acuminate.	SONORA.	126
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4b. KERNELS RED (*T. v. pyrothrix* Al.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT; spike clavate.	GRANDPRIZE.	127
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1b. SPIKE AWNED.

2a. GLUMES GLABROUS.

3a. GLUMES WHITE.

4a. KERNELS WHITE (*T. v. graecum* Kcke.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.

Spike fusiform.	DEMOCRAT.	128
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Spike clavate.

Kernels small; beaks 3-20 mm.

long.	SENECA CHIEF.	128
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Kernels midsize; beaks 2-10 mm.

long.	OATKA CHIEF.	128
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Stem purple; spike clavate.	MAMMOTH AMBER.	129
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SPRING HABIT.

Stem white.	PALISADE.	129
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Stem purple.	PROPO.	130
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KERNELS MIDLONG TO LONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

	TREADWELL.	130
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SPRING HABIT.

	BAART.	131
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KERNELS SEMIHARD TO HARD.

SPRING HABIT.	TALIMKA.	132
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4b. KERNELS RED (*T. v. erythrospermum* Kcke.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.		
Plant early.	NEBRASKA No. 23.	132

Plant midseason.

Plant midtall.

Beaks 1-3 mm. long.	GLADDEN.	133
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Beaks 2-10 mm. long.	GIPSY.	133
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1b. SPIKE AWNED—Continued.

2a. GLUMES GLABROUS—Continued.

3a. GLUMES WHITE—Continued.

4b. KERNELS RED—Continued.

KERNELS SHORT TO MIDLONG—Continued.

KERNELS SOFT TO SEMIHARD—Continued.

WINTER HABIT—Continued.

Stem white—Continued.

Plant midseason—Continued.

Plant tall.....	VALLEY.....	Page. 134
	WISCONSIN PEDIGREE No. 40.....	135
Plant late.....	SIBLEY.....	135
Stem purple.....		
Spike fusiform.....	FULCASTER.....	135
	MAMMOTH RED.....	138
Spike clavate.....	DIAMOND GRIT.....	139
	GOLDEN CROSS.....	139

SPRING HABIT.

Beaks 1-2 mm. long.....	CHAMPLAIN.....	139
Beaks 1-15 mm. long.....	JAVA.....	140
Beaks 3-25 mm. long.....		
Plant short, early.....	ERIVAN.....	141
Plant tall, midseason.....	CONVERSE.....	142

KERNELS SEMIHARD TO HARD.

WINTER HABIT.

Kernels semihard.

Glumes white to yellowish.

Beaks 1-3 mm. long.....		
Plant midseason.....	MINTURKI.....	142
Plant late.....	HUSSAR.....	142
Beaks 2-8 mm. long.....	PESTERBODEN.....	143
Glumes often black striped.....	BLACKHULL.....	143

Kernels hard.

Beaks 2-8 mm. long.....	TURKEY.....	144
	IOWA No. 404.....	147
	IOWA No. 1946.....	147
	MONTANA No. 36.....	148
	NEBRASKA No. 60.....	148
	WISCONSIN PEDIGREE No. 2.....	148
Beaks 3-25 mm. long.....	KANRED.....	148
	BELOGLINA.....	149
	BACSKA.....	149

SPRING HABIT.

Stem white; plant midseason.

Beaks 1-2 mm. long.....	PRESTON.....	150
Beaks 2-20 mm. long.....	KOTA.....	152
Stem purple; plant early; beaks 1-5 mm. long.....	PIONEER.....	152

KERNELS MIDLONG TO LONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.

Spike inclined; glumes black striped.....	RUDY.....	153
Spike nodding.....	GLUTEN.....	154

Stem purple.

Beaks 1-2 mm. long.....	NIGGER.....	154
Beaks 2-10 mm. long.....	SILVERSHEAF.....	155

SPRING HABIT.

Beaks 2-15 mm. long.....	FRETES.....	155
Beaks 5-30 mm. long.....	DIXON.....	156

KERNELS SEMIHARD TO HARD.

SPRING HABIT; beaks 5-45 mm. long.....	CHUL.....	156
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3b. GLUMES BROWN.

4a. KERNELS WHITE (*T. v. erythroleucon* Kcke.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.....	LINK.....	157
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1b. SPIKE AWNED—Continued.

2a. GLUMES GLABROUS—Continued.

3b. GLUMES BROWN—Continued.

4a. KERNELS WHITE—Continued.

KERNELS SHORT TO MIDLONG—Continued.

KERNELS SEMIHARD TO HARD.

WINTER HABIT.....	GENESEE GIANT.....	Page. 157
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KERNELS MIDLONG TO LONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.....	Longberry No. 1.....	159
Stem purple.....	NEW AMBER LONGBERRY..	159

KERNELS SEMIHARD TO HARD.

SPRING HABIT.....	SEVIER.....	159
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4b. KERNELS RED (*T. v. ferrugineum* Al.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Spike fusiform.

Stem white.

Beaks 1-5 mm. long.

Plant midseason, tall.....	DIEHL-MEDITERRANEAN...	160
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Plant late, midtall.....	RUSSIAN.....	161
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Beaks 3-25 mm. long.....	IMPERIAL AMBER.....	162
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Stem purple; beaks 1-3 mm. long.....	GOENS.....	162
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Spike oblong; stem purple; beaks 1-10 mm.

long.....	COX.....	163
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KERNELS SEMIHARD TO HARD.

WINTER HABIT.....	YAROSLAV.....	164
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SPRING HABIT.

Stem white.

Beaks 1-2 mm. long.....	HURON.....	164
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Beaks 3-25 mm. long.....	NORKA.....	164
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Stem purple.

Shoulders usually rounding.....	LADOGA.....	165
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Shoulders elevated.....	LARAMIE.....	165
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KERNELS MIDLONG TO LONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Stem white.....	ARIETTE.....	166
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Stem purple.

Kernels soft; crease midwide, middeep.....	MEDITERRANEAN.....	166
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Kernels semihard; crease wide, deep.....	RED ROCK.....	168
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2b. GLUMES PUBESCENT.

3a. GLUMES WHITE.

4a. KERNELS WHITE (*T. v. meridionale* Kcke.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

Spike oblong.....	BEARDED WINTER FIFE....	168
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Spike clavate.....	READ.....	168
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4b. KERNELS RED (*T. v. velutinum* Al.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.

.....	RURAL NEW YORKER No.	
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57.....		169
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PRIDE OF GENESEE.....		169
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VIRGINIA.....		170
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KERNELS SEMIHARD TO HARD.

SPRING HABIT.....	PRELUDE.....	170
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KERNELS MIDLONG TO LONG.

KERNELS SOFT TO SEMIHARD.

SPRING HABIT.....	HUMPBAC.....	171
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3b. GLUMES BROWN.

4a. KERNELS RED (*T. v. barbarossa* Al.).

KERNELS SHORT TO MIDLONG.

KERNELS SOFT TO SEMIHARD.

WINTER HABIT.....	PENQUITE.....	171
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DESCRIPTIONS, HISTORY, DISTRIBUTION, AND SYNONYMY OF COMMON WHEAT VARIETIES.

WINTER BLUESTEM.

Description.—Plant winter habit, midseason, midtall; stem glaucous, white, strong; spike awnless, fusiform, middense, erect to inclined; glumes glabrous, yellowish white, midlong, wide; shoulders midwide, square to elevated; beaks midwide, obtuse, 0.5 to 1.5 mm. long, slightly incurved; apical awns few, 5 to 40 mm. long; kernels white, midlong to long, soft to semihard, elliptical to ovate; germ small; crease midwide, middeep; cheeks rounded; brush small to midsized, midlong.

Winter Bluestem has the hardy winter characteristics of Turkey, but lacks vigor and is usually a comparatively low yielder.

History.—This variety originated at the Washington Agricultural Experiment Station, Pullman, Wash., as the result of a cross between Turkey and Pacific Bluestem (170, p. 6). It was distributed for commercial growing by the Washington Agricultural Experiment Station from 1912 to 1914.

Distribution.—Grown in the State of Washington to a very limited extent.

MARTIN (MARTIN AMBER).

Description.—Plant winter habit, midseason, tall; stem white, strong; spike awnless, linear-fusiform, lax, nodding; glumes glabrous, white, long, midwide; shoulders midwide, oblique to square; beaks wide, acute, triangular, 1.0 mm. long; apical awns few, 5 to 15 mm. long; kernels white, midlong, soft, ovate; germ small; crease midwide, middeep; cheeks rounded; brush midsized, midlong.

This variety is distinguished from other winter varieties of the group by its long, lax, tapering spike. A pure line (C. I. No. 4463) has been isolated which is resistant to bunt. A spike of Martin wheat is shown in Plate VI, Figure 2.

History.—Martin (Martin Amber) originated from a single plant found as a mixture in a field of Clawson by Henry S. Bunnell, of Junius, Seneca County, N. Y., about 1875 (152). Several names were early applied to it. It was called Armstrong by R. T. Halloway, of Penn Yan, Yates County, N. Y., who first distributed it in 1880 (16, p. 666). The variety, however, never became widely grown under that name. In 1882, J. A. Everitt, seedsman, of Watertown, Pa., named it Martin Amber and distributed it widely (16, p. 666). The variety became commercially established under that name. It was also distributed in 1882 as Landreth, by David Landreth & Son, seedsmen, of Philadelphia, Pa. (152).

Distribution.—Grown to a limited extent as Martin Amber in Arizona, Idaho, Illinois, Michigan, Ohio, Oregon, Pennsylvania, Utah, and Washington, and under the names of synonyms in Kentucky, Missouri, New York, North Carolina and Tennessee. The distribution of Martin wheat is shown in Figure 19.

Synonyms.—Amber, Armstrong, Landreth, Satisfaction, Silver Chaff, and White Amber. Amber and White Amber are local names used for the variety on farms in Idaho and Washington. The name White Amber is also used in Marion County, Ky. Armstrong and Landreth, as indicated above, are names given it by seedsmen many years ago, but are not now in use. Satisfaction is the name under which a similar wheat was obtained by the United States Department of Agriculture, but this was evidently wrongly labeled and the name should not be used for this variety. Silver Chaff is an old name for the variety (15) and was early recognized by the Ohio Agricultural Experiment Station as a synonym for Martin (Amber) (116). The variety is still grown under this name in Kentucky, Michigan, Missouri, New York, North Carolina, Ohio, and Tennessee.

PROHIBITION.

Description.—Plant winter habit, midseason to late, midtall to tall; stem glaucous, white, strong; spike awnless, linear-oblong to subclavate, middense, erect to inclined; glumes glabrous, white, midlong, wide; shoulders narrow to midwide, oblique to rounded; beaks wide, obtuse, 0.5 to 1.0 mm. long; apical awns few, 1 to 15 mm. long; kernels white, midlong, soft, ovate, humped; germ small; crease wide, middeep; cheeks rounded; brush small, midlong.

The distinctly humped kernels is a character which can be used to distinguish this variety from the other soft white wheats of the Pacific Northwest. Spikes, glumes, and kernels of this variety are shown in Plate VIII, A.

History.—B. H. Irvine, a pioneer in the Willamette Valley of Oregon, distributed the variety in that State. He obtained, through a Dr. Crawford,

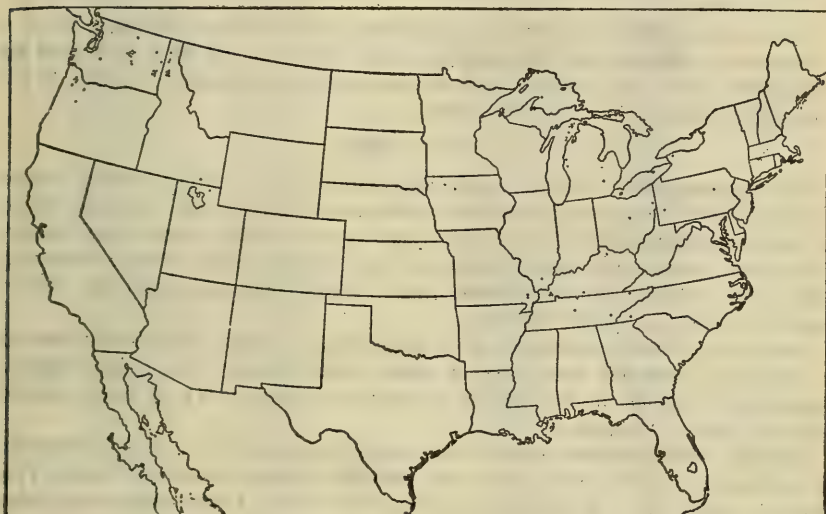


FIG. 19.—Outline map of the United States, showing the distribution of Martin wheat in 1919. Estimated area, 37,800 acres.

several varieties from the Commissioner of Agriculture for trial, about 1885, and grew them on his farm about 9 miles northeast of Scio, in Linn County. One variety proved superior to anything then grown in the vicinity. Having forgotten the name of the variety, he called it Prohibition, as he had just become an ardent member of that political party. Later he claimed to have found the descriptive sheet which accompanied the original seed and learned that the name was "Ricenbrod." A Rickenbrode wheat was reported as a new variety tested at Mount Pleasant, Ontario County, N. Y., in 1883 (150). It was distributed in the Western States by the Commissioner of Agriculture about 1885 and is without doubt the wheat referred to. Nothing further is known concerning its origin.

Distribution.—Grown in Linn and Marion Counties, Oreg., principally in the Red Hills section of the Willamette Valley.

Synonyms.—Prohi and Rickenbrode. Prohi is a colloquial shortening of the name of the variety, which recently has come into use for it in the Pacific Northwest. Rickenbrode apparently was the original name of the variety, but has not been used for many years.

GREESON.

Description.—Plant winter habit, midseason, midtall; stem glaucous, white, midstrong to strong; spike awnless, oblong-fusiform, middense, erect to inclined; glumes glabrous, white, midlong, wide; shoulders wide, square to elevated; beaks wide, obtuse, 1 mm. long; apical awns few, 2 to 20 mm. long, somewhat incurved; kernels white, midlong, soft, ovate, acute; germ midsized; crease midwide, deep; cheeks rounded, brush small, midlong.

The variety differs principally from Prohibition in being slightly earlier and in having slightly longer and laxer spikes and wider glumes and shoulders.

History.—According to W. H. McLean, of Whitsett, N. C., "this variety originated by a man whose name was Greeson, and has been grown in this country for a number of years and is very popular."⁷ He reported that it constituted 40 per cent of the wheat grown near Whitsett, Guilford County, N. C., in 1919.

Distribution.—Grown in Chatham, Randolph, and Guilford Counties, N. C.

Synonym.—Greensboro. Because the seed was obtained at a fair held at Greensboro, N. C., this name is used for the variety in Randolph County, N. C., where this wheat is most widely grown.

WHITE WINTER.

Description.—Plant winter habit, late, midtall; stem white, strong; spike awnless, oblong, bluntish, dense, erect; glumes glabrous, white, midlong, broad at base; shoulders wanting to oblique; keel incurved above, beaks wide, obtuse, 1 mm. long; apical awns few, 3 to 20 mm. long; kernels white, short to midlong, soft, ovate, slightly humped; germ small; crease midwide, middeep; cheeks rounded; brush midsized, midlong.

The variety differs principally from Prohibition in being later and in having a distinctly incurved keel, smaller germ, and blunter kernel tip. Spikes, glumes, and kernels of this variety are shown in Plate VIII, *B*, and a single spike in Plate V, Figure 3.

History.—White Winter is one of the oldest wheats grown in western Oregon. It is reported to have been one of the principal wheats raised in Oregon Territory in 1855 (97). It probably is of English origin. Other names have been applied to the variety at times, but none has become generally used.

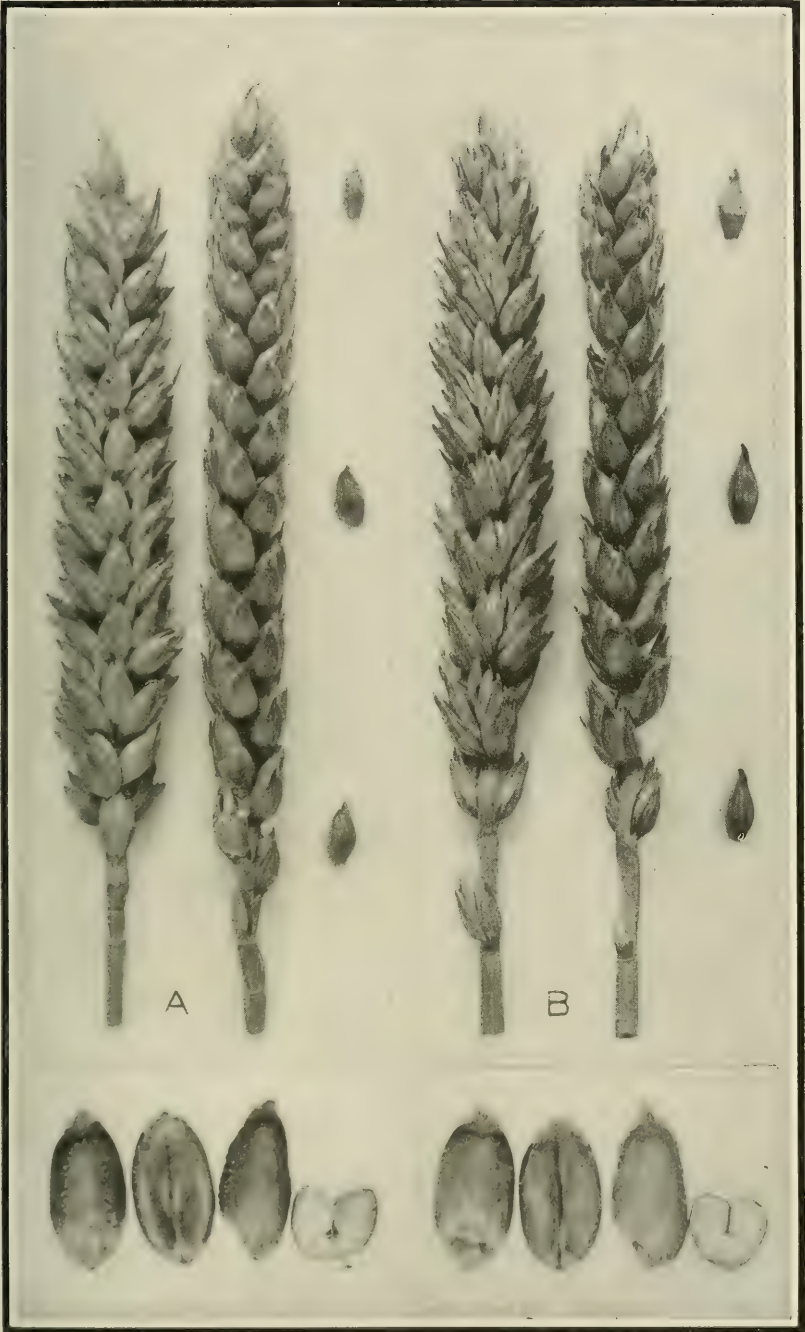
Distribution.—Grown in 10 counties of western Oregon and in Siskiyou County, Calif. It is one of the principal varieties grown in the Willamette Valley.

Synonyms.—Bishop's Pride, Oregon White, and Wold's White Winter. Bishop's Pride is, for the most part, White Winter. Dr. W. L. Bishop, of Dundee, Yamhill County, Oreg., claims he originated it as a result of a hybrid obtained by sowing several varieties in a field and letting them cross naturally. Oregon White is a name commonly used by farmers in the Willamette Valley of Oregon for the White Winter variety. Wold's White Winter is a name under which the variety is known in Washington County, Oreg. Joseph Connell, of Hillsboro, Oreg., reported in the Wheat Varietal Survey of 1917 that Wold's White Winter originated in Kent County, England, and had been grown in Washington County for about 40 years.

CHALLENGE (WEBB'S CHALLENGE WHITE).

Description.—This variety is similar to White Winter except that it is slightly taller and has a slightly longer spike, which tapers abruptly at the apex instead of being nearly blunt.

⁷ Letter from W. H. McLean, dated July 19, 1919, on file in the Office of Cereal Investigations.



PROHIBITION (A).

WHITE WINTER (B).

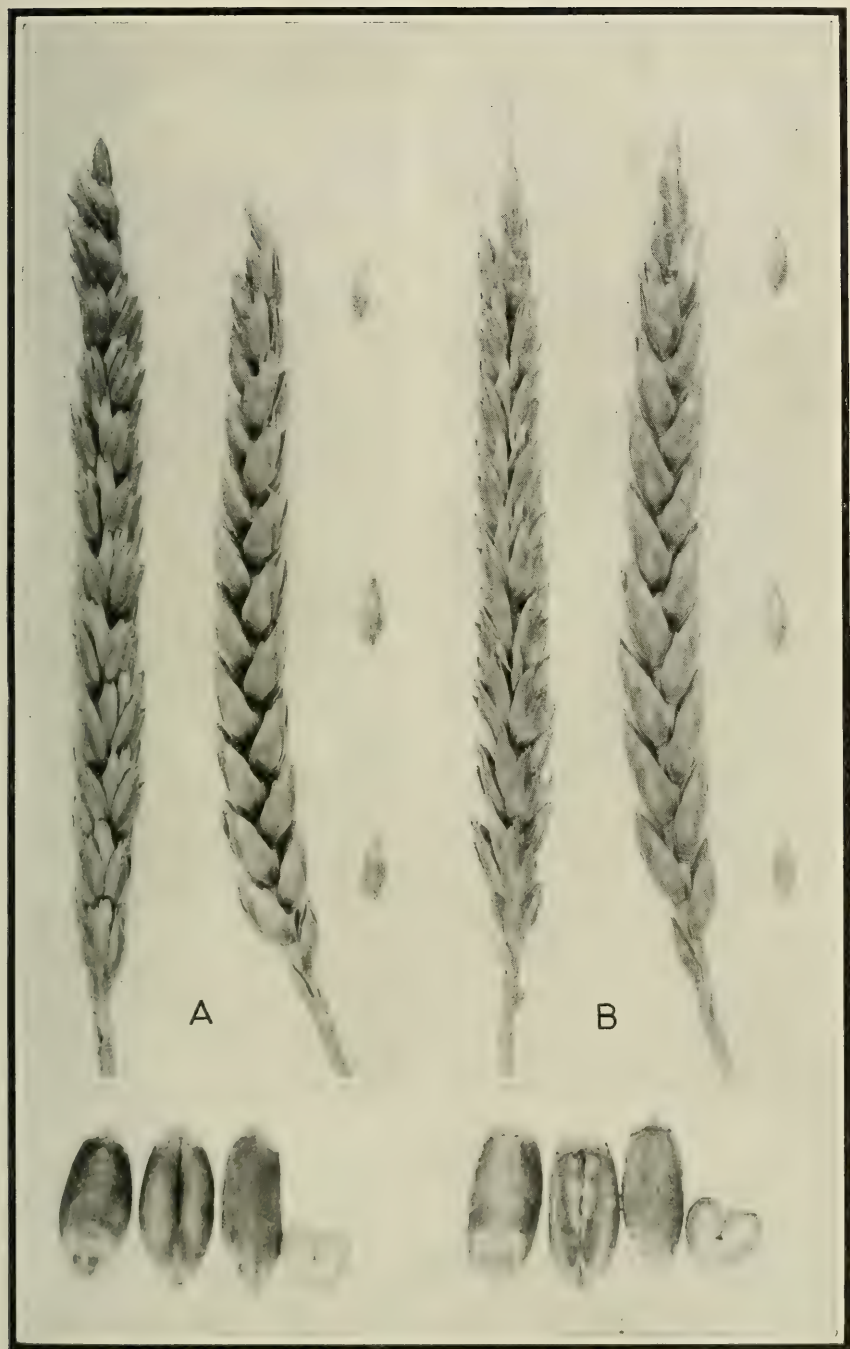
Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



EATON (A).

COLORADO NO. 50 (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



TOUSE (A).

DEFIANCE (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



PACIFIC BLUESTEM (A).

GYPSUM (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

History.—Challenge (Webb's Challenge White) is a selection from the White Victoria wheat of England (133, p. 220) made by Mr. Webb, of the Webb Seed Co., Wordsley, Stourbridge, England. The details of the introduction of this variety into the United States are not known.

Distribution.—Grown experimentally by the Oregon Agricultural Experiment Station. It is not known to be commercially grown in the United States.

EATON.

Description.—This variety is similar to both White Winter and Challenge, differing only in having the spike slightly clavate rather than oblong. Spikes, glumes, and kernels of Eaton wheat are shown in Plate IX, A.

History.—The origin of Eaton wheat is undetermined. It is thought by the writers to be an old variety of English origin. It has been grown by the Oregon Agricultural Experiment Station since 1894.

Distribution.—Grown in Idaho County, Idaho, and in Clackamas, Columbia, and Multnomah Counties, Oreg.

WHITE WONDER.

Description.—Plant winter habit, midseason, midtall; stem glaucous, white, midstrong; spike awnless, short, oblong, middense to dense, inclined to nodding; glumes glabrous, white, midlong, midwide; shoulders narrow, oblique to square; beaks wide, obtuse, 1 mm. long; apical awns several, 2 to 20 mm. long; kernels white, short, soft, oval to ovate; germ small to midsized; crease midwide, middeep; cheeks rounded; brush midsized, midlong.

This variety differs from Greeson principally in having spikes inclined or nodding rather than erect and glumes with much narrower shoulders.

History.—The origin of this variety is undetermined. A sample was obtained from Clark Sprigg, of Walkersville, W. Va., who reported that it made up 25 per cent of the wheat grown in his vicinity in Lewis County in 1919.

Distribution.—Grown in Lewis County, W. Va., and in Oneida County, N. Y.

SATISFACTION (SMITH'S RUST PROOF).

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awnless, clavate, middense, inclined; glumes glabrous, white, midlong, narrow to midwide; shoulders narrow, oblique to square; beaks wide, obtuse, 1.0 mm. long; apical awns several, 5 to 15 mm. long; kernels white, short to midlong, soft, oval to ovate; tips often nearly truncate; germ midsized; crease wide, middeep; cheeks angular; brush midsized, midlong.

Satisfaction is distinct in having a clavate spike. A spike of it is shown in Plate IV, Figure 3, and in Plate V, Figure 5.

History.—The origin of Satisfaction is undetermined. It was grown by the Ohio Agricultural Experiment Station at Wooster, Ohio, in 1904 (204, p. 38). A similar variety called Smith's Rust Proof was grown by the Ohio Agricultural Experiment Station as early as 1895 (115, p. 22).

Distribution.—Both Satisfaction and Smith's Rust Proof are grown at several experiment stations in the eastern United States. Neither is definitely known to be grown commercially, although Rust Proof was reported as a variety grown in Michigan, North Carolina, South Carolina, Tennessee, and Texas. All samples obtained from these sources, however, proved to be other varieties.

Synonym.—Smith's Rust Proof. The origin of this variety or name is undetermined. As indicated above, it is an older wheat than Satisfaction, and the extent of its present commercial culture, if any, is uncertain.

EARLY DEFIANCE.

Description.—Plant spring habit, early, short to midtall; stem white, midstrong; spike awnless, fusiform to oblong, middense, erect; glumes glabrous, white, midlong, midwide; shoulders narrow to midwide, oblique to square; beaks wide, triangular, acute, 0.5 to 1.5 mm. long; apical awns wanting to few; kernels white, midlong, soft to semihard, ovate to elliptical, germ usually small; crease midwide, middeep; cheeks usually rounded; brush mid-sized, midlong.

The variety differs from Defiance in being a week to 10 days earlier and in having kernels slightly longer and more pointed.

History.—This is a strain of Defiance wheat recently distributed by the Germain Seed Co., of Los Angeles, Calif.

Distribution.—Grown in San Diego County, Calif.

COLORADO NO. 50.

Description.—This variety is similar to Early Defiance except that it has several apical awns which vary from 2 to 15 mm. long. Spikes, glumes, and kernels of Colorado No. 50 are shown in Plate IX, B.

History.—This is a strain of Defiance wheat developed at the Colorado Agricultural Experiment Station. It was first distributed about 1909 or 1910 by Prof. W. H. Olin, then of that station. The Barteldes Seed Co., of Denver, Colo., later distributed the variety, recommending it for growing at altitudes of 8,000 feet or more (45).

Distribution.—Grown in Rio Grande County, Colo. It is said by the Barteldes Seed Co. to be grown in the higher elevations in Rio Grande and Routt Counties and in the San Luis Valley.

TOUSE.

Description.—Plant spring habit, midseason, midtall; stem white, slender, weak; spike awnless, fusiform, middense, erect to inclined; glumes glabrous, white, midlong, narrow to midwide; shoulders narrow, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns usually wanting; kernels white, midlong, soft, ovate to nearly elliptical; germ usually small; crease narrow to midwide, middeep; cheeks rounded; brush small, midlong.

This variety is not vigorous, has a very weak stem, and shatters readily. It has continued in cultivation partly as a mixture with club wheat which prevents lodging, many growers stating they grow Club and Touse. Spikes, glumes, and kernels of Touse wheat are shown in Plate X, A.

History.—Touse is an old wheat of Idaho and Utah. It was reported grown in Utah as early as 1870. The origin of Touse wheat is not definitely determined, but it is thought by the writers to be the Touzelle wheat which was introduced by the Federal Government from Marseille, France, the record of which was as follows:

There have been two importations—one of 140 bushels in August, 1869, and one of 123 bushels in January, 1870. A small distribution was made in September, 1869, chiefly through Senators and Representatives in Congress (8, pp. 128-129).

Distribution of this variety by the Federal Government continued for several years. In the early seventies reports of the variety were received from several sections of the United States. It was distributed as a winter wheat, and reports from the Eastern States show that it did not prove sufficiently hardy for those sections, while in California, Colorado, and Oregon the reports indicated that it was grown successfully.

Distribution.—Grown sparingly in Arizona, Idaho, Montana, Nevada, Utah, and Wyoming.

Synonym.—White Touse. This name is used by some growers in Utah, Idaho, and Wyoming.

DEFIANCE.

Description.—Plant spring habit, midseason, tall; stem white, weak to mid-strong; spike awnless, fusiform, middense, erect to inclined; glumes glabrous, white, midlong, narrow; shoulders narrow, oblique to square; beaks wide, obtuse, somewhat incurved, 1.0 mm. long; apical awns wanting to few, 3 to 12 mm. long; kernels white, midlong, soft, ovate; germ usually small; crease wide, middeep; cheeks usually angular; brush mid-sized, midlong.

Defiance wheat is variable in many of the characters above described, indicating that there are several different strains within the variety. Spikes and kernels of this wheat are shown in Plate X, B.

History.—Defiance is the result of a cross of White Hamburg as the male parent and Golden Drop as the female parent, which was made by Cyrus G. Pringle, in the Champlain Valley, near Charlotte, Vt., in 1871. It was first distributed in 1878 by B. C. Bliss & Sons, as Pringle's Defiance. It showed three distinct types of grain. Prof. A. E. Blount took some of this wheat to the Colorado Agricultural Experiment Station, where he grew it during a number of years and made careful selections. Three commercial varieties were developed from it, viz, Early Defiance, Colorado No. 50, and Regenerated Defiance. Prof. A. H. Danielson, who succeeded Professor Blount at the Colorado station, has recorded the following interesting history of the origin of Defiance wheat:

Before closing I want to give a little résumé of the history of Colorado's most famous wheat. The mother of Defiance traces back to southern England and was originated by F. F. Hallett, of Brighton, in the sixties. He is the man who first used the word pedigree as applied to wheat. The mother was a decided club-shaped type with pretty red grain, somewhat soft, and Hallett called it the Golden Drop. It was quite popular in England, but never amounted to much either in this country or Australia. From England it went to Canada, where a man named Pringle got it as the Canada Club. The father of Defiance was a Dutchman from Germany, and rather soft at that, but white. It came from Hamburg, from whence lots of wheat emigrated in those days. It had a long, coarse broad head, a big white berry, and a rank-growing constitution with good ability to stand on its feet. Good old White Hamburg has long since been dead and buried to cultivation, at least under that name, but was largely grown on the Pacific slope during the early days of cereal culture there (76).

Distribution.—Grown from spring sowing mostly on irrigated land in Colorado, Idaho, Nebraska, Nevada, New Mexico, Utah, and Wyoming, and from fall sowing in western Oregon and southern Arizona and California. The distribution of Defiance and Regenerated Defiance wheat is shown in Figure 20.

Synonym.—Pringle's Defiance. As indicated above, this was the name under which the variety was first distributed by a seed company. In recent years the name Defiance has been generally used.



FIG. 20.—Outline map of the western United States, showing the distribution of Defiance and Regenerated Defiance wheat in 1919. Estimated area, 194,400 acres.

RINK.

Description.—Plant spring habit, midseason, midtall; stem white, strong; spike awnless, broadly fusiform, middense, inclined; glumes glabrous, yellowish white, midlong, midwide; shoulders wide, usually square; beaks wide, acute, curved, 1 to 1.5 mm. long; apical awns many, 2 to 10 mm. long, occurring nearly throughout the spike, and distinctly incurved; kernels white, short to midlong, soft, ovate, slightly humped; germ usually small; crease midwide, deep; cheeks rounded; brush mid-sized, midlong to long.

This variety is distinct in having incurved apical awns occurring nearly throughout the entire length of the spike. Spikes of Rink wheat are shown in Plate IV, Figure 4, and Plate V, Figure 2.

History.—The origin of Rink wheat is undetermined. It was reported to have been grown in Washington County, Oreg., since 1909.

Distribution.—Grown in Benton, Polk, Washington, and Yamhill Counties, Oreg.

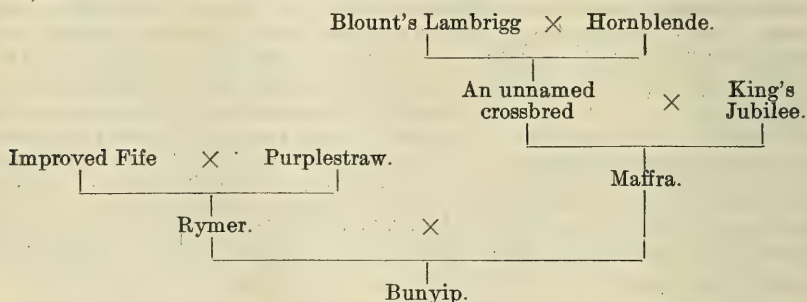
BUNYIP.

Description.—Plant spring habit, early, midtall; stem white, strong; spike awnless, oblong, dense, erect; glumes glabrous, yellowish white (brown striped), midlong, midwide; shoulders midwide, oblique to square; beaks narrow to midwide, acute, 0.5 mm. long; apical awns few, 3 to 12 mm. long; kernels white, midlong, soft to semihard, ovate; germ mid-sized; crease midwide, mid-deep; cheeks angular; brush midlong, mid-sized to large.

The glumes of this variety are distinctly brown striped, which sometimes gives the appearance of a brown-glumed variety.

History.—Bunyip is an Australian variety originated by William Farrer, the well-known plant breeder of New South Wales, Australia. Its origin has been recorded as follows:

It is a crossbred, produced as the result of mating two other crossbreds, Rymer and Maffra, together. Rymer, the mother plant, was produced as the result of crossing Purplestraw on to Improved Fife, the latter being a Manitoba variety. Maffra was the product of King's Jubilee, mated with an unnamed crossbred (Blount's Lambrigg $\times$ Hornblende). Its pedigree is, therefore, as follows:



The cross was made in 1897 and named in 1901 (188, p. 189).

Bunyip was first introduced into the United States (S. P. I. No. 38345) in May, 1914, by the United States Department of Agriculture (197). In 1915 a sample of the variety was included in the Australian exhibit at the Panama-Pacific International Exposition at San Francisco, Calif. A part of this seed was obtained, together with that of several other varieties, by the Sperry Flour

Co. and grown on their experiment station near Stockton, Calif. Of several varieties grown, the Bunyip was selected as the most promising and was increased and distributed for commercial growing in California.

Distribution.—Grown in San Joaquin and Stanislaus Counties, Calif.

PACIFIC BLUESTEM.

Description.—Plant spring habit, midseason, tall; stem white, strong; spike awnless, linear-oblong, dense, erect; glumes glabrous, yellowish white, sometimes becoming a light brown, midlong, wide; shoulders wide, square to elevated; beaks wide, oblong, obtuse to truncate, 0.5 to 1 mm. long; apical awns several, 8 to 20 mm. long; kernels white, midlong, soft to semihard, ovate, sometimes becoming oval; germ midsize; crease wide, middeep; cheeks usually angular; brush midsize, midlong.

This variety can be easily identified by its broad, square shoulders and broad, blunt beaks. The variety is a high-yielding wheat under favorable climatic conditions, and the grain is considered above the average in quality for bread making among the white-kerneled wheats grown in the Pacific Coast States. Spikes, glumes, and kernels of this wheat are shown in Plate XI, A, and a single spike in Plate VI, Figure 5.

History.—Pacific Bluestem is an old wheat of the Pacific coast area, most commonly known as Bluestem and White Australian. The variety came to America from Australia. White Lammas was the leading wheat variety of Australia during the earliest years of wheat production in that country. According to Cobb (70, p. 9), White Australian of California is identical with White Lammas of Australia. It apparently was introduced into the United States in the early fifties as White Australian or Australian. During the period from 1852 to 1866 (179, p. 176; 38, p. 138; 84, p. 586) its culture became established in California under the name White Australian. Since that time it has remained the principal variety grown in that State. Bluestem is the name under which the variety became established in Washington and Oregon. According to W. P. Church, of Walla Walla, Wash., the wheat known as Bluestem in that section came from two introductions, the first from Australia in 1882 and the second from New Zealand in 1896. The following item was recorded concerning the first introduction:

Most of the wheat raised in that locality (Walla Walla County) is what is known as the Bluestem variety. It is an Australian wheat, introduced in this country by Sibson, Church & Co. George Delaney was the first to sow the wheat in this country in 1882, but W. H. Reed, of the firm of Reed & Co., grain merchants, was the first to bring it into general use (21).

Concerning the second introduction, Mr. Church has stated that "it consisted of 14 sacks and contained a mixture of 10 to 15 per cent of red kernels contained in bearded heads." Mr. Church stated further that the introductions came under the name of Purplestraw Tuscan. This name, however, was never used for the wheat in the United States. The wheat is not similar to the Purplestraw Tuscan wheat of Australia, but is somewhat similar to, but not identical with, the White Tuscan and Silver King varieties.

It is not known how the name "Bluestem" came to be applied to the variety, as it does not have the purple stem common to many varieties of wheat and is not similar to any of the other five varieties grown in the United States under that name. To distinguish this Bluestem wheat from the others it has recently been called Pacific Bluestem. In Washington and Oregon the Pacific Bluestem wheat became as popular as the White Australian did earlier in California, and

until recent years it has been the principal spring wheat grown in the so-called "Inland Empire."

Distribution.—Grown as Bluestem in Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, and Washington. The distribution is shown in Figure 21.

Synonyms.—Australian, Bluestem, Chile, Palouse Bluestem, White Australian, White Bluestem, White Chile, White Elliott, and White Lamas.

As indicated above, Australian, Bluestem, White Australian, and White Lamas are old names for the variety in Australia and the United States. Palouse Bluestem and White Bluestem are names which more recently came into use for this variety to distinguish it from other bluestem wheats in the United States. Chile and White Chile are names which came into use for the variety because cargoes of this wheat were received from time to time from Chile and in part were used for seed. White Elliott is a local name used for this wheat in Douglas County, Wash.



FIG. 21.—Outline map of the western United States, showing the distribution of Pacific Bluestem wheat in 1919. Estimated area, 1,363,400 acres.

MEXICAN BLUESTEM.

Description.—Mexican Bluestem is a variety similar to Pacific Bluestem, except that it is slightly shorter and earlier and has bronze rather than white to yellowish glumes. The glumes, however, never become dark enough to be classed as brown.

History.—Seed of this variety was obtained by the Washington Agricultural Experiment Station from Mexico. It was grown at the Western Washington Experiment Station, Puyallup, Wash., where it proved to be the best yielding spring wheat

in a 6-year experiment and was distributed for commercial growing in the vicinity of that station. As it differed slightly from Pacific Bluestem and was a better yielder, a distinct name seemed necessary, and Mexican Bluestem was used to indicate its origin and its similarity to Pacific Bluestem.

Distribution.—Grown in Grays Harbor and Pierce Counties, Wash.

DART (DART'S IMPERIAL).

Description.—Plant spring habit, early to midseason, midtall; stem white to yellowish, strong; spike awnless, subclavate, middense, erect; glumes glabrous, white, midlong, midwide; shoulders narrow to midwide, oblique to square; beaks wide, obtuse, 1 to 2 mm. long; apical awns several, 3 to 20 mm. long; kernels white, midlong, soft to semihard, ovate, acute; germ small to midsized; crease midwide, shallow; cheeks rounded, brush small, midlong, collared.

History.—This is an Australian variety. Its origin is recorded by Richardson (158, p. 124) to be as follows:

This popular variety was originated by Thomas Dart, of Nhill, Victoria, formerly of Lucindale, South Australia, and is a selection from a purple-straw variety. It is one of the oldest varieties in general cultivation at the present time.

The earliest introduction of this wheat into the United States is thought to have been in 1915, when it was included in the Australian exhibit of wheats at

the Panama-Pacific International Exposition at San Francisco, Calif. At the close of the exposition, the Sperry Flour Co. obtained a part of the sample and grew it at their experiment station near Stockton, Calif., where it was later increased and distributed for commercial growing in the State.

Distribution.—Grown in San Joaquin County, Calif.

GYP SUM.

Description.—Plant spring habit, midseason, midtall; stem glaucous, white, strong; spike awnless, subclavate, middense, inclined; glumes glabrous, white, midlong, wide; shoulders wide, oblique to square; beaks wide, triangular, acute, 0.7 to 1.2 mm. long; apical awns several, 5 to 15 mm. long; kernels white, midlong, soft to semihard, ovate; germ mid-sized; crease midwide, middeep; cheeks usually angular; brush mid-sized, midlong.

This variety differs principally from Defiance in being shorter and in having shorter and broader subclavate spikes and broader glumes with squarer shoulders and longer beaks. The kernels have a distinctly rough coat. Spikes, glumes, and kernels of Gypsum are shown in Plate XI, B, and a single spike in Plate VI, Figure 6.

History.—Gypsum is recorded by Carleton (58, p. 83) as of hybrid origin. It was developed at the Colorado Agricultural Experiment Station, Fort Collins, Colo., during the eighties, by Prof. A. E. Blount. The variety became known in Australia as Blount's Lambrigg (72, p. 4; 61, p. 219). During recent years, in the United States, the variety has been grown as Colorado Special, that name having been in use as early as 1912 on the Rexburg Bench, in southern Idaho.

Distribution.—Grown as Colorado Special in Madison, Teton, Franklin, Fremont, and Power Counties, Idaho.

Synonyms.—Blount's Lambrigg and Colorado Special.

SURPRISE (PRINGLE'S SURPRISE).

Description.—Plant spring habit, late, midtall; stem slightly glaucous before maturity, white, strong, coarse; leaves broad; spike awnless, clavate, dense, erect; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 1.0 mm. long; apical awns several, 3 to 15 mm. long; kernels white, short to midlong, soft, oval to ovate; germ small to mid-sized; crease wide, deep; cheeks rounded to angular; brush mid-sized, midlong.

This wheat varies somewhat from the preceding description. Several distinct types have been selected from it, and many more could be. Like Defiance, the variety probably was not pure when first distributed. It is a high-yielding wheat when grown under very favorable conditions and is well adapted for growing under irrigation.

History.—Surprise was originated by Cyrus G. Pringle, in the Champlain Valley, near Charlotte, Vt., in the late seventies. Concerning the origin of the variety, Mr. Pringle wrote the Rural New Yorker as follows:

My No. 4 (thus numbered only in samples of wheat sent to Prof. Blount for trial) is a cross between the Chile Club, the soft, white variety, widely grown in the Pacific coast, and the Michigan Club, once common over our Northwestern States. Under the name of Pringle's Surprise, the entire stock was sold two or three years ago by my agent to the Commissioner of Agriculture, Le Duc, for distribution (17).

It evidently was widely distributed in several Western States in the eighties. It was advertised in California farm papers at that time, but with the decline of the wheat industry in that State the identity of the variety became lost. It

later became known by several different names. In recent years it has been called California Gem in that State, while in Utah, where it is most widely grown, it is best known as California Club, although several other names have been used. The name Pringle's Surprise has continued in use in Grays Harbor County, Wash., where it was introduced about 1883.

Distribution.—Grown in California, Idaho, Oregon, Utah, Washington, and Wyoming, mostly under the synonyms here recorded. The distribution is shown in Figure 22.

Synonyms.—Australian Club, Bay, California Club, California Gem, Excelsior, Golden Gate Club, Imperial Club, Pride of California, Silver Chaff, Silver Club, Smith Club, University Gem, White Russian.

Australian Club is the name under which the variety is grown in Lane County, Oreg. Bay is a name used for the variety in Mendocino County, Calif. As stated



FIG. 22.—Outline map of the western United States, showing the distribution of Surprise wheat in 1919. Estimated area, 60,900 acres.

above, California Club is the name under which the variety is best known, particularly in Utah. Although not a club wheat, this and other names ending in Club have been used for the variety for many years. The name Golden Gate Club is used in San Luis Obispo County, Calif., Imperial Club in Summit County, Utah, Silver Club in Duchesne County, Utah, and Smith Club in Lake County, Calif. In the last mentioned county the name Pride of California also is used for the variety.

California Gem is a name under which the variety has been grown and distributed by the California Agricultural Experiment Station since about 1899 (28). University Gem has also been used by the California Agricultural Experiment Station. The name Excelsior is in use for the variety in Salt Lake County and Silver Chaff in Morgan and other counties of Utah. One sample obtained under the latter name

varied in having a less clavate spike, but was otherwise similar. White Russian is a name used for the variety by the Washington Agricultural Experiment Station.

DICKLOW.

Description.—Dicklow differs from Surprise in having spikes slightly longer and laxer and stems and leaves much more glaucous during the heading and blossoming stages of growth. It is a high-yielding variety under irrigation, but will shatter badly if allowed to become overripe before harvest. Spikes, glumes, and kernels are shown in Plate XII, A.

History.—Dicklow was developed by selection and its uniformity indicates that it is a pure line or nearly so. The origin of this strain of Surprise wheat has been recorded by Aicher (34, p. 20) as follows:

Mr. James Holly, of Utah County, Utah, obtained some California Club wheat from northern California and seeded it on his farm. Excellent results were obtained, and he called the attention of his neighbor, Mr. Richard Low, to his new wheat. Mr. Low obtained some and grew it. He noticed that the wheat contained different types and proceeded to select the type which he liked best. He grew this selection for several years, and the neighbors soon began clamoring



DICKLOW (A).

REGENERATED DEFIANCE (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



NEW ZEALAND (A).

PILCRAW (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

for "Dick" Low's wheat. As the wheat became spread over that section of Utah, it lost its personal connection with "Dick" Low and became known simply as Dicklow wheat.

Distribution.—Grown in Idaho, Montana, Utah, and Wyoming. It is most widely grown under irrigation in southern Idaho, where it was introduced in 1912 and 1913. The distribution is shown in Figure 23.

Synonym.—Jim Holly. This name was used by some growers of Dicklow wheat when the strain was first being distributed, but it has since largely gone out of use.

BOBS.

Description.—Plant spring habit, early, midtall; stem white, strong; spike awnless, fusiform, middense, erect; glumes glabrous, white to yellowish, mid-long, midwide; shoulders wide, square; beaks wide, acute, short, 0.3 mm. long, sometimes nearly wanting; apical awns wanting; kernels white, usually short, hard, oval to ovate, with truncate tip; germ mid-sized; crease midwide to wide, middeep to deep; cheeks angular, brush mid-sized, short.

The Bobs variety is distinct in having no apical awns and very short beaks. The kernels are hard and have a distinctly short brush. It usually is a comparatively low-yielding variety under favorable conditions, but under conditions of drought often will yield well in comparison with others. The flour from it is very strong, exceeding in bread-making value the other white-kerneled varieties grown in the United States. A spike of Bobs wheat is shown in Plate IV, Figure 1.

History.—The Bobs variety was originated by William Farrer, of New South Wales, Australia. It is reported to be the result of a hybrid between a barley and a wheat. Such a cross was never obtained by other workers and is now generally considered to be impossible. Furthermore, the original progeny showed no trace of barley characters. Considerable doubt, therefore, exists as to whether Mr. Farrer actually obtained a cross. The origin of Bobs as recorded in Australian literature is as follows:

Bobs was produced in 1896 as a result of mating a variety of barley, called Nepaul or Bald Skinless barley, with a strain of Blount's Lambrigg wheat, which, for record purposes, was called M. (F.), but which became known later as Early Lambrigg. As the result of the artificial pollination effected, only one shrivelled grain was produced. This was planted, and very little difficulty was experienced in fixing a variety from it. Four years later the progeny of this cross had become fixed and was named Bobs.

This variety is really a hybrid and not a crossbred, for it is the result of mating two distinct species, viz, a wheat and a barley, together. A crossbred is the result of mating two varieties of the same species together (188, p. 187).

Distribution.—Grown by experiment stations in the Pacific Coast States and commercially to a very small extent in San Luis Obispo and Monterey Counties, Calif.

QUALITY.

Description.—Plant spring habit, early, short to midtall; stem white, strong; spike awnless, fusiform, middense, erect; glumes glabrous, yellowish white, short, wide, easily shattered; shoulders wide, oblique to square; beaks wide, acute, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels white, short



FIG. 23.—Outline map of the Pacific Northwest, showing the distribution of Dicklow wheat in 1919. Estimated area, 164,600 acres.

to midlong, hard, oval; germ mid-sized; crease midwide, middeep to deep; cheeks rounded; brush mid-sized, midlong.

Quality is a spring wheat and is not winter hardy when fall sown. It also shatters very badly in dry climates.

History.—Quality wheat was first distributed by Luther Burbank, of Santa Rosa, Calif., in 1918. In his catalogue of "New Standard Grains" (52) in 1918, Mr. Burbank's first published statement concerning Quality wheat is as follows:

This season I offer a superior early hard white wheat suited to all climates wherever wheat can be grown; as a summer wheat in the cold far northern climates and as a winter crop in the United States and most wheat-growing countries. It is especially adapted also to short seasons and soils and dry climates. A superior white milling wheat which makes the best light, sweet, nutritious bread and pastry. . . . This early, hardy "Quality" wheat which I offer this season will not yield as much as some of the coarse macaroni wheats in some warm, dry sections, but for general culture, with its unusual hardness and extreme earliness, uniformity, superior milling and bread-making qualities, it stands alone. It most resembles in all these respects the hard northern wheat "Prize Marquis," but has a vitreous white berry of quite different appearance and quality and of about the same specific gravity as granite (52).

The seed was originally sold at \$5 per pound, or \$45 for 10 pounds, i. e., at the rate of \$270 a bushel. Concerning these extravagant claims and prices, Buller (50, p. 235) has made the following comment:

But Mr. Burbank is only just beginning his work as an introducer of new wheats, and the writer can not help feeling that in penning his advertisement of Quality he allowed his enthusiasm for his new cereal to be mixed a little too freely with his ink. . . . When Mr. Burbank tells us that Quality . . . has kernels with about the same specific gravity as granite, surely he is addressing us in the language of hyperbole.

Distribution.—Grown experimentally and to a small extent commercially in California, Montana, and Oklahoma, in 1920.

WHITE FIFE.

Description.—Plant spring habit, midseason, midtall; stem white, midstrong; spike awnless, fusiform, middense, erect; glumes glabrous, white to yellowish, short, midwide, shoulders midwide, oblique to square; beaks midwide, acute, 0.5 to 1.0 mm. long; apical awns few, 5 to 15 mm. long; kernels white, short to midlong, hard, ovate; germ mid-sized; crease midwide, middeep; cheeks angular; brush mid-sized, midlong. A spike of this wheat is shown in Plate IV, Figure 2.

History.—White Fife is thought to be a white-kerneled separation from the well-known Red Fife wheat of Canada, although its exact origin is undetermined. It was grown by the Colorado Agricultural Experiment Station in 1879 from seed obtained from Minnesota (46, p. 40). It was first grown in the varietal experiments at Indian Head, Saskatchewan, Experimental Farm in 1889, where it was continued in the experiments until 1911. During this 23-year period it outyielded Red Fife by nearly 1.5 bushels per acre. The variety was used by Dr. A. P. Saunders as one of the parents of crosses from which originated the varieties Huron, Percy, and Prelude. The White Fife variety was used also by Prof. A. E. Blount as a parent stock for several of his hybrids made at the Colorado Agricultural College about 1888.

Distribution.—Grown sparingly in Polk County, Minn., Sheridan County, Nebr., and Richland County, N. Dak. It was reported in 1904 to have been grown to a considerable extent in some parts of Manitoba and the Northwest Territories.

WHITE FEDERATION.

Description.—Plant spring habit, early, short to midtall; stem white, strong, spike awnless, oblong, middense, erect; glumes glabrous, white, short, wide; shoulders wide, square; beaks narrow, acute, 0.5 mm. long; apical awns wanting or nearly so; kernels white, short, semihard to hard, ovate, with truncate tip; germ midlarge; crease midwide, middeep; cheeks rounded; brush mid-sized, midlong.

This variety is very similar to Hard Federation, except that it has white instead of brown glumes. The plant also is slightly taller and the kernels are not quite as hard. It has proved to be a high-yielding wheat in California and Oregon.

History.—White Federation is of Australian origin, but as far as the writers are aware its history has never been recorded in Australian literature. The following sentence, however, indicates its origin:

The seed (hard kernels selected from Federation by Mr. J. T. Pridham, from which Hard Federation originated) was propagated, and in 1910 the occurrence of white heads was noticed, and from then until 1912 distinctly white heads were common among the brown (30, p. 664).

The name White Federation has been used for the wheat at the Cowra Experiment Farm, New South Wales, Australia, since 1915, when a field of 3 acres of the variety was grown (154).

It was introduced into the United States by the United States Department of Agriculture (197) in 1916 (S. P. I. No. 42104), when 5 ounces of seed were presented by A. E. V. Richardson, agricultural superintendent of the Department of Agriculture at Melbourne, Victoria, Australia. It was first grown in a 5-foot row in the classification nursery at the Sherman County branch station, Moro, Oreg., in 1916. Since 1918 it has been grown at the Plant-Introduction Garden, Chico, Calif., and because of its high yield at that point it has been increased and distributed for commercial growing in California (67, p. 24).

Distribution.—Grown at experiment stations in California, Washington, Oregon, Idaho, and Utah and commercially in Butte County, Calif., in 1920.

LYNN (LYNN RUST PROOF).

Description.—Plant spring habit, midseason, midtall to tall; stem white, glaucous, strong, stout; spike awnless, linear-oblong, middense, erect; glumes glabrous, yellowish white, midlong, midwide; shoulders narrow to midwide, oblique to elevated; beaks midwide, obtuse, 1 mm. long; apical awns few, 2 to 15 mm. long; kernels white, short, semihard to hard, ovate; germ mid-sized; crease midwide, deep; cheeks angular; brush mid-sized, midlong, collared.

The variety differs from both Defiance and Surprise in having an oblong spike and fairly hard kernels. The Lynn is resistant to some forms of stem rust under California conditions.

History.—This variety probably is a selection from Defiance or Surprise. According to R. B. Luther, Templeton, Calif., Lynn (Lynn Rust Proof) was first propagated by Lynn Brothers, of Paso Robles, San Luis Obispo County, Calif.

Distribution.—Grown in San Luis Obispo County, Calif., where it was introduced about 1914.

Synonyms.—Arizona No. 39, Pride of Oregon. According to W. E. Bryan, plant breeder at the Arizona Agricultural Experiment Station, "Arizona No. 39 was selected originally from a field of soft wheat grown in the Yuma Valley

in 1912." It is very similar to Lynn except that the kernels are somewhat harder. Pride of Oregon was distributed by the Murphy Seed Store, Albany, Oreg. The variety is very similar to Lynn and Arizona No. 39, except that the kernels are harder than either. Both Arizona No. 39 and Pride of Oregon have the rust resistance of Lynn.

REGENERATED DEFIANCE.

Description.—Plant spring habit, late, midtall to tall; stem glaucous when green; white, strong; spike awnless, linear-oblong, middense, erect; glumes glabrous, white, midlong, narrow; shoulders narrow, oblique to square; beaks narrow, triangular, acute, 0.8 to 1.5 mm. long; apical awns wanting to few, 3 to 10 mm. long; kernels white, short, hard, broadly oval to ovate; germ mid-sized; crease wide, deep; cheeks usually angular; brush midsized, midlong, sometimes collared.

This variety differs from Defiance in being later and taller and in having a longer and broader spike and a shorter and harder kernel. The kernel differs from Dicklow in being shorter and harder and in having a deeper crease. Spikes, glumes, and kernels of this variety are shown in Plate XII, *B*, and a single spike in Plate VI, Figure 4.

History.—This is one of several selections of Defiance wheat made by Prof. A. E. Blount at the Colorado Agricultural Experiment Station. In 1903, Prof. A. H. Danielson found this particular selection in a bottle marked Defiance, which Professor Blount had left some 12 years previous. He planted all of the seed found, about 50 kernels, but only 3 produced seed. This seed was grown and further selected and increased until 1907, when it was distributed as "Regenerated Defiance."

Distribution.—Grown mostly under irrigation in Colorado, South Dakota, Idaho, Montana, New Mexico, Nebraska, and Wyoming. The distribution of this strain of Defiance can not be separated from Defiance itself, so the distribution of both are shown in Figure 20.

NEW ZEALAND.

Description.—Plant spring habit, midseason, midtall to tall; stem white, strong; spike awnless, linear-oblong, middense, inclined; glumes glabrous, white, midlong, narrow; shoulders narrow, wanting to oblique; beaks midwide, obtuse, 0.5 to 1 mm. long; apical awns few, 3 to 30 mm. long; kernels white, midlong to long, soft, ovate; germ midsized; crease midwide, middeep; cheeks rounded; brush midsized, midlong.

This variety is very similar to Pacific Bluestem, but differs principally in having a longer and laxer spike, narrower shoulders, and larger kernels. Spikes, glumes, and kernels of this wheat are shown in Plate XIII, *A*.

History.—The origin of New Zealand wheat is undetermined. It is possibly the Blé de Zélande wheat of France, described by Heuzé (112, p. 79). According to J. H. Wittuer, county agent, Vernal, Utah, New Zealand wheat was introduced into Utah about 1890, where it has been grown sparingly until the present time.

Distribution.—Grown in 5 counties in Idaho and 11 counties in Utah.

Synonyms.—Ninety-Day and Ruby. These names are recorded as synonyms for the variety by Stewart (186, p. 166), Ninety-Day being used in Salt Lake County and Ruby in Sanpete County, Utah.

PILCRAW (PILCRAW ENORMOUS).

Description.—Plant spring habit, midseason, midtall, stem white, strong; spike awnless, clavate, dense, erect; glumes glabrous, white to yellowish, short,

wide; shoulders midwide to wide, square to elevated; beaks narrow, acute, 0.5 to 1.0 mm. long; apical awns several, 8 to 40 mm. long; kernels white, midlong to long, soft, ovate, distinctly humped; germ midsized; crease midwide, middeep to deep, pitted; cheeks rounded; brush large, midlong to long.

This variety is quite similar to Surprise, but differs principally in being earlier and shorter and in having more numerous and longer apical awns and larger and humped kernels. Spikes, glumes, and kernels of this wheat are shown in Plate XIII, B.

History.—Hugh A. Crawford, Napa, Calif., obtained this variety from a neighbor who said he had noticed an unusual stool of wheat near an unfrequented road and who cut it when ripe and started experimenting with it. Mr. Crawford bought the original seed in 1913 and increased it until in 1917 he had 360 acres growing at Winters, Calif. He named it Pilcrow Enormous and distributed it.

Distribution.—Grown in Napa and Sacramento Counties, Calif.

RICE.

Description.—Plant winter habit, early, midtall; stem white, midstrong; spike awnless, fusiform, dense, erect; glumes glabrous, white, short, midwide; shoulders midwide to wide, oblique to square; beaks nearly wanting; apical awns wanting to few, 1 to 10 mm. long; kernels pale red, short to midlong, soft, ovate; germ small to midsized; crease midwide, shallow to middeep; cheeks angular; brush midsized, midlong.

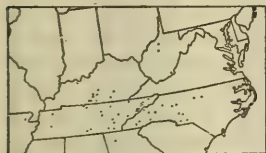


FIG. 24.—Outline map of a portion of the east-central United States, showing the distribution of Rice wheat in 1919. Estimated area, 30,900 acres.

This variety is very similar to Zimmerman, but differs principally in having a more fusiform although denser spike, wider shoulder, and longer beaks and apical awns. The kernels also are harder. Spikes, glumes, and kernels of Rice wheat are shown in Plate XIV, A.

History.—The origin of Rice wheat is undetermined, although it is known to be an old variety in the United States. In 1883 it was first reported as a "new variety tested by M. F. P., Mount Pleasant, Ontario County, N. Y." (150, p. 657), and it also was mentioned in that year by C. S. Plumb (153, p. 310) in a paper entitled "The Wheats of the World," read at the Batavia Institute.

Distribution.—Grown in Arkansas, Georgia, Kentucky, North Carolina, Tennessee, Virginia, and West Virginia. The distribution is shown in Figure 24.

Synonyms.—Early Rice, Red Rice, White Rice. These are names used for the variety by growers in one or another of the States named.

MINHARDI.

Description.—Plant winter habit, midseason, midtall; stem white, slender, strong; spike awnless, fusiform, middense, erect; glumes glabrous, white, midlong, narrow; shoulders narrow, wanting to oblique; beaks wide, obtuse, 1 mm. long; apical awns several, occurring on upper third of spike, usually incurved, 2 to 15 mm. long; kernels red, short to midlong, soft to semihard, ovate; germ small; crease midwide, middeep; cheeks usually rounded; brush midsized, midlong. This is one of the most winter hardy wheats grown in America.

History.—The Minhardi was originated at the Minnesota Agricultural Experiment Station. It is one of the progeny of a cross made between Odessa

(female) and Turkey (male) in 1902, when Prof. W. M. Hays was in charge of the plant breeding. Several selections from this cross grown in 1915 showed unusual promise for winter hardiness, and, after further experiments reported by Hayes and Garber (106, p. 17-28), the most hardy strain (Minn. No. 1505) was named Minhardi and distributed.

Distribution.—Grown at experiment stations in the Great Plains area and commercially in Minnesota in 1920.

Synonym.—Minnesota No. 1505. This is the Minnesota accession number under which Minhardi was known and grown until it was named.

LOFTHOUSE.

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awnless, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders wanting to narrow, oblique; beaks wide, obtuse, 1 mm. long; apical awns several, 5 to 30 mm. long; kernels red, midlong, soft, ovate; germ small; crease midwide, middeep; cheeks usually angular; brush small, midlong.

There is some confusion as to the identity of this variety. It frequently has been referred to as white kerneled and often is confused with the Kofod variety.

History.—A wheat by the name of Lofthouse has been grown in Utah since about 1890. The sample from which were grown the plants described above was obtained by the Nephi, Utah, substation from the State station at Logan, Utah, in 1904. The origin of the variety can not be accurately traced, and considerable confusion exists as to whether the variety originally was a white-kerneled or red-kerneled wheat. According to Prof. J. B. Nelson, now of the Montana Agricultural Experiment Station, the variety became established in Utah from seed distributed by a Mr. Lofthouse, a farmer at Paradise, Utah, about 16 miles south of Logan. Professor Nelson states that in 1893 or 1894, in a conversation with Mr. Lofthouse regarding the best varieties of wheat for dry farming, he was told that Mr. Lofthouse had received a sample of soft white winter wheat from the United States Department of Agriculture a year or two previously, which promised to produce large yields and was a good milling wheat. He stated that he had sufficient seed on hand at that time to sow a good acreage, that he was going to sell it to the dry farmers at market value, and that he had named the wheat Lofthouse. The wheat was hardy, standing the winter better than other varieties, and soon became the most extensively grown winter wheat in northern Utah and southern Idaho. While the above statement shows that the wheat originally was white kerneled, the wheat grown at Nephi, Utah, since 1904 is red kerneled.

Distribution.—Grown in Bannock, Cassia, and Franklin Counties, Idaho, and Boxelder, Cache, Sevier, and Washington Counties, Utah. Part of this distribution was reported as white kerneled.

Synonyms.—Winter La Salle, Winter Nellis. Winter La Salle is a name used as a synonym for Lofthouse wheat in Utah. It is thought to be the name under which the wheat later named Lofthouse was sent to Utah by the United States Department of Agriculture. The writers, however, are without a history of the origin or distribution of this wheat. Winter Nellis is also a name commonly used for Lofthouse wheat in Utah.

BIG FRAME.

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awnless, fusiform, middense, inclined; glumes glabrous, white, midlong,



RICE (A).

BUFFUM No 17 (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



LEAP (A).

WALKER (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

midwide; shoulders midwide, oblique to square; beaks midwide, obtuse, 0.5 mm. long; apical awns several, often incurving on upper third of spike, 3 to 20 mm. long; kernels red, midlong, soft, ovate to oval; germ small; crease midwide, middeep; cheeks rounded; brush mid-sized; midlong.

History.—The origin of this wheat is undetermined. It is recorded by Carleton (58, p. 44) as a wheat of American origin. It was an important variety in Nebraska in the nineties, but now has practically disappeared from cultivation.

Distribution.—Grown in Butler County, Nebr.

BUFFUM NO. 17.

Description.—Plant winter habit, hardy, late, midtall; stem white, midstrong; spike awnless, linear-fusiform, middense to lax, inclined; glumes glabrous, white to yellowish, long, narrow; shoulders wanting to narrow, oblique; beaks wide, obtuse, 1 mm. long; apical awns several, 3 to 30 mm. long; kernels, red, short to midlong, soft to semihard, ovate; germ small; crease midwide, middeep; cheeks usually rounded; brush mid-sized to large, long.

This variety has unusual winter hardiness. Its spikes, glumes, and kernels are illustrated in Plate XIV, B.

History.—It originated from the selection of a single plant having an awnless spike, found in a field of Turkey wheat by B. C. Buffum, of Worland, Wyo. Seed of this selection was increased and was distributed commercially by Mr. Buffum under the above name in 1912. In an unpublished article on this wheat, dated May 20, 1915, and presented at the cereal conference, Berkeley, Calif., in June, 1915, the origin of the variety is given by Mr. Buffum as follows:⁸

The discovery of a beardless mutant was not premeditated. . . . Occasional reversion in large fields to the bearded Kharkof type and some of the second-generation variations from crosses with No. 17 definitely prove its origin to be that stated, a mutant of Turkey Red.

Distribution.—Grown in Sheridan and Washakie Counties, Wyo.

LEAP (LEAP'S PROLIFIC).

Description.—Plant winter habit, early, midtall; stem white, midstrong; spike awnless, fusiform, middense to lax, inclined to nodding; glumes glabrous, yellowish white, midlong, midwide, easily deciduous; shoulders midwide, oblique to square; beaks wide, acute, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels red, midlong, soft, ovate; germ small; crease midwide to wide, middeep; cheeks usually angular; brush small, midlong. Spikes, glumes, and kernels of Leap wheat are shown in Plate XV, A.

History.—The variety is reported to have originated from a single plant found in a field of Mediterranean by the oldest son of J. S. Leap, of Virginia. From the five heads gathered in 1901, Mr. Leap increased the wheat until 1905, when he thrashed 190 bushels grown from 10 bushels of seed. T. W. Wood & Sons, seedsmen, of Richmond, Va., first distributed the variety as Leap's Prolific. General distribution of the wheat started about 1907, and it since has become very popular (137, p. 44).

⁸ Buffum, B. C., Buffum's No. 17. Paper at Cereal Conference, June, 1915. Unpublished.

Distribution.—Grown as Leap's Prolific in Alabama, Connecticut, Delaware, Georgia, Illinois, Indiana, Kentucky, Maryland, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. The distribution is shown in Figure 25.

Synonyms.—Hastings Prolific, Woods Prolific, and Woolf. Hastings Prolific is a name used for Leap wheat in Alabama, Georgia, and South Carolina. Woods Prolific is used for the variety in Tennessee and Virginia. These names probably are derived from the names of the seed firms selling it. Woolf is a name used for the Leap variety in Muhlenberg County, Ky.

ONTARIO WONDER.

Description.—Plant winter habit, midseason, midtall to tall; stem white, midstrong; spike awnless, fusiform, middense, nodding; glumes glabrous, white, midlong, narrow; shoulders wanting to narrow, oblique to rounded; beaks wide, obtuse, 1.0 mm. long; apical awns few, 3 to 10 mm. long; kernels pale red, midlong, soft, ovate; germ small to mid-sized; crease midwide, mid-deep; cheeks angular to rounded; brush mid-sized, midlong.

History.—This is a Canadian variety of undetermined origin. The variety was grown in the United States by the Ohio Agricultural Experiment Station as early as 1888 (113, p. 28).

Distribution.—So far as known this variety is grown only experimentally in the United States, although it is commercially grown in Ontario.

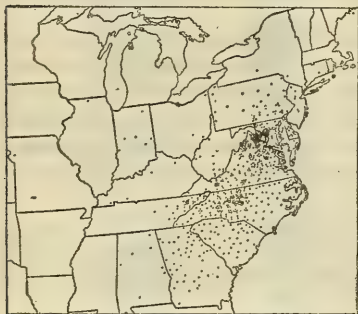


FIG. 25.—Outline map of a portion of the eastern United States, showing the distribution of Leap wheat in 1919. Estimated area, 513,100 acres.

ZIMMERMAN.

Description.—Plant winter habit, early, midtall; stem white, strong; spikes awnless, oblong-fusiform, middense, erect to inclined; glumes glabrous, white, short, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels

pale red, usually short, soft, ovate; germ small to mid-sized; crease midwide, middeep; cheeks rounded; brush small, midlong.

This variety is quite similar to Fultz, but differs principally in being slightly earlier and having white straw and a smaller kernel.

History.—Zimmerman is reported to have been originated about 1837 near Frederick, Md., by Henry Zimmerman, who noticed three heads of singular appearance near the edge of one of his wheat fields. They were saved, the seed sown and increased, and at the end of the sixth year he had over 60 bushels; in the seventh year the wheat was sold to the public (118). The kernel is described as "of a rich yellow." This might indicate that it was a white-kerneled wheat. From 1847 to 1850 the name "Zimmerman" was applied in literature to both a white and a red wheat. References to red-kerneled Zimmerman wheat in the fifties show it was quite widely grown in Maryland, Virginia, and Pennsylvania, and by the early nineties it was an important wheat in eastern Kansas, where it is still grown.

Distribution.—Grown sparingly in eastern Kansas and in Missouri.

WALKER.

Description.—Plant winter habit, early to midseason, midtall to tall; stem white, strong; spike awnless, oblong-fusiform, middense, inclined; glumes glabrous, white, short, wide; shoulders midwide to wide, oblique to square; beaks wide, obtuse, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels pale red, mid-sized, soft, ovate; germ mid-sized; crease midwide, middeep; cheeks rounded; brush small, midlong.

Walker differs from Zimmerman in being slightly later and taller and has a more inclined spike, wider glumes, and larger kernels and germ. Spikes, glumes, and kernels of the Walker wheat are shown in Plate XV, B.

History.—The origin of Walker is undetermined. It is known to be an old variety of the eastern United States and was being replaced by Tappahannock in Jackson County, N. C., in 1871 (8, p. 131).

Distribution.—Grown in Arkansas, Illinois, Kentucky, Missouri, Oklahoma, Tennessee, and Texas. This distribution is shown in Figure 26.

HARVEST QUEEN.

Description.—Plant winter habit, midseason, tall; stem white, strong; spike awnless, oblong, dense, erect to inclined; glumes glabrous, white, midlong, midwide; shoulders wide, oblique to square; beaks wide, obtuse, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels dull red, midlong, soft, ovate; germ mid-sized; crease midwide to wide, middeep; cheeks rounded; brush mid-sized, midlong.

This variety is distinct in having tall, bright, strong straw and a thick oblong spike. Spikes, glumes, and kernels of this variety are shown in Plate XVI, A.

History.—The name Harvest Queen was used early for a white wheat, but this use apparently has been discontinued. The earlier names under which the wheat described above was known were Black Sea, Oregon Red, and Red Cross. The name Harvest Queen is claimed by E. S. Marshall,⁹

of De Soto, Kans., to have been applied to the variety by him. He selected a tall promising stool of the wheat from some other variety in 1895, increased it in 1896, and named it in 1897. Mr. Marshall stated that he selected the name Harvest Queen, because he thought he had a better wheat than Harvest King, which was then being widely advertised by the J. A. Everitt Seed Co., of Indianapolis, Ind. For several years he and his father, Conrad Marshall, continued to select the variety. Most of the Harvest Queen grown in Johnson County, Kans., and vicinity apparently is from seed originally distributed from the Marshall farm. Harvest Queen wheat was advertised and distributed by the Barteldes Seed Co., of Lawrence, Kans., and by the J. A. Everitt Seed Co., of Indianapolis, Ind. The latter firm (89) claim to have distributed it first in 1896, which scarcely could be possible if Mr. Marshall is correct in his dates.

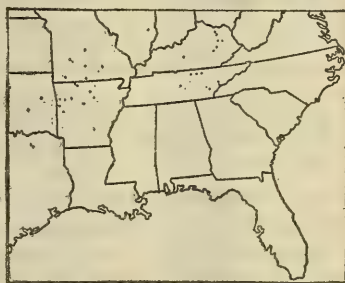


FIG. 26.—Outline map of the southeastern United States, showing the distribution of Walker wheat in 1919. Estimated area, 24,300 acres.

⁹ Interview by J. A. Clark, S. C. Salmon, and C. E. Graves, on June 6, 1921.

Distribution.—Grown as Harvest Queen in Arkansas, Illinois, Indiana, Kansas, Michigan, Missouri, Ohio, Oklahoma, Pennsylvania, Tennessee, West Virginia, and under the synonymous names in Iowa and Nebraska. Figure 27 shows the distribution of the variety.

Synonyms.—Black Sea, Canadian, Canadian Fife, Imported Scotch, Italian Wonder, Kansas Queen, May Queen, New 100, Oregon Red, Prairie Queen, Prizetaker, Red Cross, Salzer's Prizetaker, Virginia Reel, and Winter Queen.

Black Sea is a name used for the variety in Doniphan County, Kans., where it has been grown under that name for eight years. Black Sea was an important winter wheat in Wisconsin in 1849 (62, p. 205). This name also has long been used in the United States for a bearded spring wheat. Canadian and Canadian Fife are names used for the variety in Marion County, Mo.

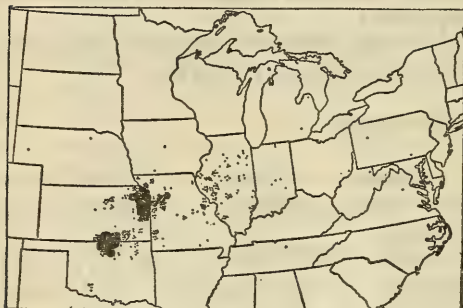


FIG. 27.—Outline map of a portion of the United States, showing the distribution of Harvest Queen wheat in 1919. Estimated area, 1,007,600 acres.

Imported Scotch grown in Webster County, Mo., apparently is Harvest Queen. Concerning this wheat, J. C. Preston, of Seymour, Mo., stated in correspondence with the Office of Cereal Investigations as follows:

I got this wheat on the farm of Milton, near Leuchars, Fife County, Scotland in 1910. A Mr. Thompson was tenant there. Just brought about one handful in my pocket. I was told that it was first-prize wheat at the Royal Show in 1909.

Italian Wonder is a name used for the variety in Cowley County, Kans.

Concerning this wheat, C. M. Wallis, of Winfield, Kans., wrote the Office of Cereal Investigations the following information:

About 10 years ago Tom Isnagle found scattering heads of exceedingly large and well-developed berry. He went through and selected them and planted the seed. He got such good results he continued until he raised enough to seed his farm and called it Italian Wonder; then began to sell seed.

Kansas Queen, May Queen, Prairie Queen, and Winter Queen are names used for the Harvest Queen variety in several counties in northeastern Kansas. There is considerable confusion in the name May, as it is applied to several varieties. May Queen, therefore, should not be confused with Red May and Little May. New 100 is a designation used for Harvest Queen wheat in Howard County, Mo. Oregon Red is an old name for the variety and is still used in Cowley County, Kans., and Grant and Payne Counties, Oklahoma.

Red Cross is the name under which the above-described wheat has been grown in Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, and Nebraska. The name has been commonly used for the Harvest Queen variety in Missouri for 25 years or more. Its origin is undetermined. It undoubtedly is an earlier name for the variety than Harvest Queen, but as the name Red Cross has been applied to other varieties and as this variety has become so well known as Harvest Queen, the latter name is used here.

Prizetaker and Salzer's Prizetaker are names under which the Harvest Queen variety is grown in Illinois and neighboring States, although the name was used by the John A. Salzer Seed Co., of La Crosse, Wis., for the Goldcoin variety.



HARVEST QUEEN (A).

PROSPERITY (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



RED RUSSIAN (A).

CLIMAX (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

Virginia Reel is a name used for Harvest Queen wheat in Douglas County, Kans., where, according to H. A. Colles, of Sibley, Kans., it has been grown for 20 years.

PROSPERITY (AMERICAN BRONZE).

Description.—Plant winter habit, midseason, midtall; stem glaucous when green, white, strong, coarse; spike awnless, linear-oblong, broad, middense, nodding; glumes glabrous, white, midlong, wide; shoulders wide, oblique to square; beaks wide, obtuse, 1 mm. long; apical awns few, 3 to 10 mm. long; kernels red, midlong, soft, ovate; germ mid-sized; crease wide, deep; cheeks angular; brush mid-sized, midlong.

This variety is marked by its broad, nodding spike and the very glaucous appearance of the entire plant while immature. Plate XVI, *B*, shows spikes, glumes, and kernels of this variety.

History.—It was originated by A. N. Jones, of Newark, Wayne County, N. Y. Mr. Jones first called it No. 8, but later named it American Bronze.¹⁰ It was first advertised and distributed in 1890 by Peter Henderson & Co., seedsmen, of New York City, and was said by them to be the result of a cross between Martin Amber and Fultz (110). The name Prosperity came into use for the variety about 1895 (27). The origin of this name is undetermined, but the variety is now grown more widely as Prosperity than as American Bronze, and as the former is a more desirable name it is here used.

Distribution.—Grown as Prosperity in Indiana, Michigan, Missouri, Ohio, and Pennsylvania, and under its original name, American Bronze, in Michigan, New York, Ohio, and Pennsylvania. The distribution of this variety is shown in Figure 28.

Synonyms.—Dutch, Hundred Mark, International No. 8, Invincible, Michigan Red, No Name, No. 8, Red Victory, Silver Chaff, Twentieth Century, and Zinn's Golden. The name Dutch is used for the variety in Cape Girardeau and Scott Counties, Mo. In correspondence with the Office of Cereal Investigations, W. J. Meyer, of Cape Girardeau, Mo., stated:

Dutch wheat was introduced into that county from Scott County, Mo., about four or five years ago and is now more extensively grown than any other variety, and is known also as "No-Name" wheat.

Hundred Mark is a name used for the variety in Adams County, Ind., Hocking and Holmes Counties, Ohio, Calhoun County, Mich., and Westmoreland County, Pa. International No. 8 is the name under which the wheat was distributed by the International Seed Co., Rochester, N. Y. The variety is still grown under this name in Cass County, Mich., and in several counties in New York. Invincible is a name used as a synonym for American Bronze since about 1895. The origin of the name is undetermined. It was reported in 1919 from Blair County, Pa. Michigan Red is a name used for the variety in Lorain County, Ohio, for 10 years or more. No. 8 is the designation originally given

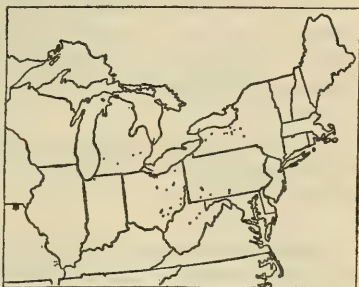


FIG. 28.—Outline map of a portion of the northeastern United States, showing the distribution of Prosperity wheat in 1919. Estimated area, 46,000 acres.

¹⁰ Printed letterheads of Mr. Jones.

the wheat by Mr. Jones, that being its trial-bed number, and later used by him as a synonym for American Bronze. Red Victory is a name applied to Prosperity by J. B. Barton, Otsego, Mich., who states that it constitutes 50 per cent of the wheat being grown near Otsego, Allegan County, Mich. He wrote the Office of Cereal Investigations concerning it as follows:

I bought the seed four years ago and the farmer brought it to this locality from about 45 miles north of me. The man I got it of did not know what it was, and the man he got it from did not know. Before it matured the first crop for me I thought it was Fultz, but as it matured I thought not, so I sent six heads to Lansing to the Michigan Agricultural College, and asked them to name it. They wrote me it was not Fultz, nor did it belong to the Fultz family, and I had a mighty good wheat, and I could name it just as well as they could. I sold all my 1918 crop for seed and, it being in the midst of the Great War, I gave it the name of Red Victory.

Silver Chaff is a name used for the Prosperity variety in New York and other Eastern States. As the name also is used for Martin wheat in this section; the distribution of the two varieties under this name is confused. Twentieth Century is a name used for Prosperity in Monroe County, Ohio, where it constitutes about 25 per cent of the wheat grown in the vicinity of Kuhn. Zinn's Golden is used for Prosperity wheat in Barbour, Braxton, and Upshur Counties, W. Va. Concerning the origin of the name, B. C. Rodibough, of Hall, W. Va., has written as follows:

It seems to have originated in Barbour County, W. Va., on the farm of a man by the name of Zinn, and has been grown in this locality quite extensively for about 15 years.

FORWARD.

Description.—This variety has not been grown by the writers. Spike samples furnished by Dr. H. H. Love show that it is somewhat similar to Prosperity, but differs in having slightly narrower and more nearly fusiform spikes and incurved apical awns.

History.—Forward was originated by the plant-breeding department of the Cornell University Agricultural Experiment Station, Ithaca, N. Y., in cooperation with the Office of Cereal Investigations, United States Department of Agriculture. During the experimental stages it was known as Cornell Selection 123-32. Concerning the variety, Dr. Love, who is in charge of the cooperative experiments at Cornell, has written as follows:¹¹

The Forward is a white chaff, beardless, red-kerneled wheat selected out of a commercial lot of Fulcaster and under test has proved to be winter hardy and a good yielder. It has outyielded Fulcaster and bids fair to be one of our best red-kerneled sorts.

Distribution.—Forward was first distributed for commercial growing in New York in the fall of 1920.

SQUAREHEAD.

Description.—Plant winter habit, late, tall; stem white, coarse, strong; spike awnless, linear-clavate, middense, erect to inclined; glumes glabrous, white, midlong, wide; shoulders midwide, oblique to square; keel incurved above; beaks wide, obtuse, 1 mm. long; apical awns few, 1 to 10 mm. long; kernels red, midlong, soft, ovate, sometimes broadly ovate; germ small to midsized; crease wide, deep; cheeks usually rounded; brush midsized, midlong to long.

This and the similar varieties, Red Russian and Sol, are distinct in being very late-maturing winter wheats and in having a very dense clavate spike and strong straw. They are adapted for growing only in mild humid sections. Their mill-

¹¹ Correspondence of the Office of Cereal Investigations, dated Mar. 19, 1921.

ing value is inferior to that of most soft red winter wheat varieties grown in the United States.

History.—This is an old English variety of undetermined origin. It is either one of several different Squarehead types or the parent of the several types recently developed in England and Sweden. Its cultivation in the United States under the name Squarehead or English Squarehead is known to date only from 1908, when the above-described wheat was brought from England by R. Clanfield, of Ballston, Oreg.

Distribution.—Grown as English Squarehead in Polk County, Oreg.

Synonyms.—Big English, Clanfield, and English Squarehead. Big English and Clanfield were reported by Hyslop (126, p. 674) as names used for Squarehead wheat in Oregon. English Squarehead is used to indicate that the variety came from England.

RED RUSSIAN.

Description.—This variety differs from Squarehead only in being of shorter stature and in having a denser and more clavate spike. Spikes, glumes, and kernels of Red Russian are shown in Plate XVII, A.

History.—This variety undoubtedly is of English origin and is, or is derived from, the old Squarehead wheat. The origin of the variety, however, is undetermined. The name Red Russian seems to be used for the variety only in the Pacific Northwest section of the United States. The variety was introduced into the Palouse section of Washington about 1890 and has always been best known there under the name Red Russian (93, p. 5).

Distribution.—Grown in Idaho, Montana, Oregon, and Washington. This distribution is shown in Figure 29.

Synonyms.—Australian Club, Early Sunrise, Squarehead, German Red, Montana Deal, and Red Walla.

Australian Club is used as a synonym for Red Russian in Lewis County, Wash. Early Sunrise and German Red are names which, according to Prof. G. R. Hyslop, of the Oregon Agricultural College, have been used for Red Russian wheat in the State of Oregon.

Squarehead is a name used for Red Russian wheat by experiment station agronomists to associate the wheat with the old and well-known Squarehead wheat of England, which it very closely resembles. Montana Deal is a name reported by J. W. Little, of Nezperce, Lewis County, Idaho, to be used as a synonym for Red Russian. Red Walla is a name sometimes used for the Red Russian variety in the Pacific Northwest, as it is the name of the subclass in which grain of the variety is marketed when sold under the United States Official Grain Standards.



FIG. 29. — Outline map of the Pacific Northwest, showing the distribution of Red Russian wheat in 1919. Estimated area, 154,900 acres.

SOL.

Description.—The Sol variety differs only slightly from Red Russian, but has a slightly less clavate spike and longer and wider leaves, which are of a darker green shade.

History.—It was originated at the Svalof Plant-Breeding Station, Svalof, Sweden, and it is said to have been derived from natural crossing, the parents probably being Swedish Island and English Stand-Up (85, p. 13). It was first put on the market by the Svalof Seed-Breeding Association in 1911. In the United States the variety was distributed as Sun by Charles H. Lilly & Co., seedsmen, of Seattle, Wash.

Distribution.—Grown as Sun in Pierce and San Juan Counties, Wash., and Sonoma County, Calif.

Synonym.—Sun. This is the English translation of the Swedish name Sol and is sometimes used for the variety.

OAKLEY (EXTRA EARLY OAKLEY).

Description.—Plant winter habit, early, midtall; stem faintly purple, midstrong; spike awnless, fusiform, middense, erect; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 15 mm. long; kernels red, midlong, soft, ovate; germ mid-sized; crease midwide, middeep; cheeks rounded to angular; brush mid-sized, midlong.

Oakley differs from Fultz in being earlier and having a more erect spike.

History.—The origin of Oakley (Extra Early Oakley) is undetermined. The variety was grown by the Kentucky Agricultural Experiment Station as early as 1891 (94, p. 112). It was reported to have been in high favor in Kentucky in the late nineties and always rated well by millers.

Distribution.—Grown in Cleveland County, N. C.

Synonyms.—Early Oakley, and Norwood or Neverfail. The latter names are used for Oakley wheat in Chatham County, N. C.

WYANDOTTE (WYANDOTTE RED).

Description.—Plant winter habit, early to midseason, midtall to tall; stem purple, midstrong; spike awnless, fusiform, middense, inclined to nodding; glumes glabrous, white, short, wide; shoulders midwide to wide, oblique to square; beaks narrow, obtuse, 0.5 mm. long; apical awns few, 1 to 15 mm. long; kernels pale red, usually short, soft, ovate; germ mid-sized; crease midwide to wide, shallow, middeep; cheeks angular; brush mid-sized, midlong.

Wyandotte differs from Fultz in being slightly earlier and shorter and in having a slightly shorter and more fusiform spike.

History.—The origin of Wyandotte (Wyandotte Red) is undetermined. It was grown by the Ohio Agricultural Experiment Station as early as 1886 from seed obtained from T. Balliet, of Nevada, Ohio (80, p. 20, 23). Seed of the variety was obtained by the Rural New Yorker in 1888 from J. A. Foote, of Crawfordsville, Ind., who grew the variety for the first time in 1887 (22, p. 591).

Distribution.—Grown in Wayne County, Ohio.

FLINT.

Description.—Plant winter habit, early to midseason, midtall; stem purple, midlong; spike awnless, oblong, dense, erect; glumes, glabrous, white, midlong, midwide; shoulders narrow, oblique to square; beaks midwide, obtuse, 0.5 to 1 mm. long; apical awns few, 2 to 40 cm. long; kernels pale red, short to midlong, soft, ovate; germ small; crease midwide, middeep; cheeks angular to rounded; brush mid-sized, midlong.

Flint differs from Fultz in being slightly earlier and shorter and in having more erect and oblong spikes, longer glumes, narrower shoulders, and longer apical awns. Spikes, glumes, and kernels of Flint wheat are shown in Plate XVIII, A.

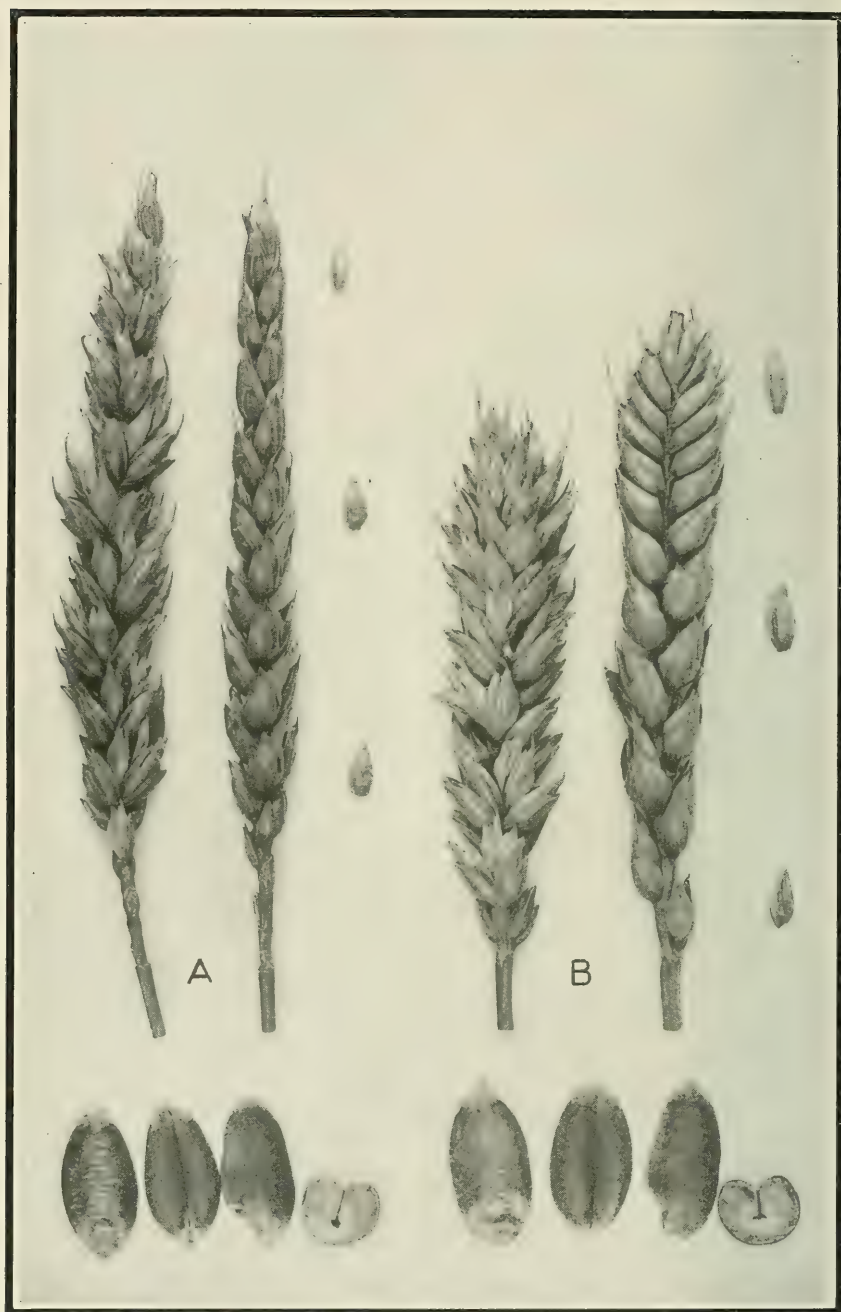
History.—The origin of Flint wheat is undetermined. It is known to be an old wheat of the eastern United States. The early names for the variety and the literature concerning them are very confusing. A White Flint, claimed to have been introduced from Spain in 1814 (103, p. 217), which became widely



FLINT (A).

PURPLESTRAW (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse sections, magnified 3 diameters.



FULTZ (A).

FULTZO-MEDITERRANEAN (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

grown in the Eastern States from 1830 to 1850, was described by Harmon as awnless, with white glumes and hard white kernels. There seems to be no winter wheat of that description now grown, and the Flint wheat now in cultivation undoubtedly has red kernels, as described above, and is similar to wheat known as Little Red May, Early May, and Rappahannock. These are all old names in American wheat literature. Little Red May is listed by Killebrew (130, p. 56) as a variety of the above description which "was brought into Tennessee by Joseph Jacobs from Missouri, no doubt having been taken there from Kentucky or Virginia. It had, however, improved by its visit, and is a very prolific, and in some sections a very popular variety." The names Little Red May, Little Red, and Little May are still in use for this variety.

Early May was listed as a variety grown in Iowa as early as 1852 (87, p. 341) which later became an important variety in that State (4, p. 518). At least some of the wheat now grown under that name is Flint. The same is true for Rappahannock, which also is now used as synonymous with Red May and in 1875 was recorded as synonymous with Michigan Amber (11).

Distribution.—Grown as Flint in Georgia, North Carolina, Ohio, South Carolina, Virginia, and West Virginia, and under the synonyms in Alabama, Arkansas, Illinois, Missouri, and Tennessee. The distribution is shown in Figure 30.

Synonyms.—Early May, Little May, Little Red, Little Red May, May, Rappahannock, Red Davie, and Red May. The name Early May, as shown above, has long been used for Flint wheat. It was reported under this name in Alabama, Arkansas, Illinois, and South Carolina. Little May was reported from Platte County, Mo., and Little Red from Arkansas, Georgia, North Carolina, Tennessee, and Virginia. Little Red May and May are also occasionally used for Flint wheat. Rappahannock and Red May were reported by J. J. Collins, Spartanburg, S. C., as synonymous names for a wheat similar to Flint which had been grown for 25 years in that vicinity. Rappahannock was also reported from Oregon County, Mo. Red Davie is a local name for Flint wheat in Surry and Wilkes Counties, N. C. According to J. B. Fells, Red Davie has been grown for 50 years in the vicinity of Elkin, N. C.

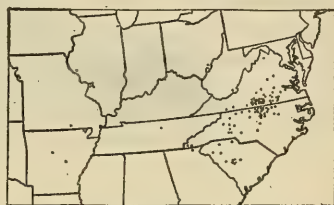


FIG. 30.—Outline map of a portion of the east-central United States, showing the distribution of Flint wheat in 1919. Estimated area, 97,200 acres.

FULTZ.

Description.—Plant winter habit, midseason, midtall; stem purple, midstrong; spike awnless, oblong-fusiform, middense, inclined to nodding; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks narrow to midwide, obtuse, 0.5 mm. long; apical awns few, 3 to 15 mm. long; kernels pale red, usually short, ovate; germ mid-sized; crease usually midwide, shallow to middeep; cheeks rounded to angular; brush mid-sized, midlong. Spikes, glumes, and kernels of this wheat are shown in Plate XIX, A.

History.—The origin of Fultz wheat has been recorded by Carleton (61, p. 199-200), as follows:

In 1862, in Mifflin County, Pa., Abraham Fultz, while passing through a field of Lancaster wheat, which is an awned variety, found three spikes of awnless wheat. He sowed the seed from these spikes the same year and continued sowing a larger amount each year until he obtained sufficient seed to distribute it pretty well over the country. It soon became a well-marked and popular variety called Fultz, from the name of the breeder. In 1871 the United States Department of Agriculture distributed 200 bushels of the wheat for seed.

Distribution.—Grown in Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin. The distribution is shown in Figure 31.

Synonyms.—Ber Ban, Bluestem, Bluestem Fultz, Economy, Everitt's High Grade, Grains o'Gold, Halver, Hickman, High Grade, Improved English, Improved Fultz, Jersey Fultz, Little Red Jersey, McKennon, New Economy, Nixon, Perpetuated Fultz, Roosevelt, Rust Proof, Shamrock, Slickhead, Tennessee Fultz, Tipton Red, and Winter Pearl.

Ber Ban is a name used for Fultz wheat in Campbell County, Tenn. Bluestem and Bluestem Fultz are names often used by farmers for Fultz wheat in the Ohio Valley, where the variety is extensively grown. Economy is

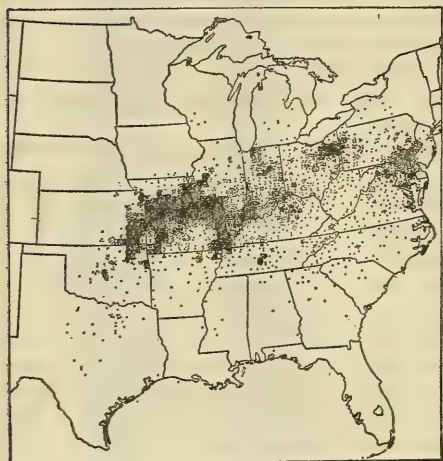


FIG. 31.—Outline map of a portion of the United States, showing the distribution of Fultz wheat in 1919. Estimated area, 4,801,100 acres.

the name under which a sample of wheat similar to Fultz was obtained in 1912 from the Cornell University Agricultural Experiment Station. A variety was grown under this name by the Ohio Agricultural Experiment Station as early as 1900. Its further history is undetermined. It is grown under this name in Kentucky, Ohio, and Virginia. New Economy is grown in Tennessee and may have the same or a different origin. Everitt's High Grade and High Grade are names first used for Fultz by J. A. Everitt in 1886, while a seedsman at Watertown, Pa. When distributed, the statement was made that it was a cross of "Martin's Amber on a number of other varieties." This statement attracted considerable comment at

the time (20, p. 706), and as the crossing was begun only four years previous to distribution it was shown that the statement was absurd and that the wheat distributed was principally the Fultz variety mixed with several other wheats. The firm, however, continued to advertise and sell the wheat, but it was later advertised as "Everitt's High Grade, or Perpetuated Fultz." High Grade and Everitt's High Grade were reported grown in Illinois, Indiana, Kentucky, Maryland, Missouri, North Carolina, Ohio, Tennessee, Virginia, and West Virginia. Grains o'Gold also was in part Fultz wheat distributed by J. A. Everitt from his O. K. Seed Store, Indianapolis, Ind. It apparently was a mixture of Fultz, Gipsy, and several other varieties. It was reported grown in Kentucky, Missouri, Ohio, Tennessee, and West Virginia. Halver and Roosevelt are names used for a wheat very similar to Fultz in Pike and Gibson Counties, Ind., where it has been grown for six years in the vicinity of Stendal. One sample differed from Fultz in having a laxer and thicker spike which nodded. Hickman is the name of a variety similar to Fultz, the origin of which is undetermined. It was grown by the Ohio Agricultural Experiment Station for the first time in 1892. It possibly is a strain of Fultz wheat named for Prof. J. Fremont Hickman, former agronomist at the Ohio station, after his death. It is grown

in Indiana and Ohio. Improved English is a name used for a variety similar to Fultz, in Cheatham County, Tenn., where it is said to have been grown for 25 years and to constitute 10 per cent of the wheat crop in the vicinity of Pleasant View. Improved Fultz is a name used for the Fultz variety by Everitt's O. K. Seed Store, Indianapolis, Ind., and the variety was so reported from Illinois, Indiana, and Kentucky. Jersey Fultz is a name used for Fultz wheat in Kentucky and is thought to be only the Fultz variety grown from seed originally from New Jersey. Little Red Jersey is a name used for Fultz in Tennessee. McKennon is a name reported for Fultz wheat in Henry County, Tenn., where it has been grown for 15 to 20 years. Nixon is a name under which samples of wheat similar to Fultz have been obtained from the Cornell University, Indiana, and Ohio Agricultural Experiment Stations. The origin of the name is undetermined, and the name was not reported in the varietal survey. Rust Proof is used for a wheat similar to Fultz in York County, S. C., where it has been grown in the vicinity of Clover for three years. The name is reported for other varieties in other localities. Shamrock is used as a name for Fultz wheat in Preble County, Ohio, where it has been grown for eight years near Eldorado. Slickhead is used as a name for Fultz wheat in Graves County, Ky. Tennessee Fultz is still another name used for Fultz wheat by Everitt's O. K. Store, Indianapolis, Ind., because they obtained their stock of seed from a valley in the high mountains of eastern Tennessee. It was reported from Indiana and Missouri. Tipton Red is a wheat very similar to Fultz grown in Jefferson County, Ind. One sample differed from Fultz in being a little later and in having a broader spike. Winter Pearl is a local name for Fultz wheat in Georgia.

ASHLAND.

Description.—According to the Kentucky Agricultural Experiment Station (32), "Ashland is very similar in character to ordinary Fultz. It has the good milling qualities of Fultz, and in addition yields better, with better straw, and is fairly resistant to scab and other diseases."

History.—This variety was developed as a pure-line selection of Fultz at the Kentucky Agricultural Experiment Station, Lexington, Ky., and was distributed to farmers in 1919 and 1920.

Distribution.—Grown to a limited extent in Kentucky in 1920.

TRUMBULL.

Description.—Trumbull differs from Fultz in being taller and in having a stronger and less purple straw and more erect spikes.

History.—Trumbull is a pure-line selection of Fultz, which was developed at the Ohio Agricultural Experiment Station, Wooster, Ohio. The selection was grown at the Ohio Agricultural Experiment Station as early as 1908. After eight years of experiments with the variety at Wooster, Prof. C. G. Williams wrote as follows regarding it:

The other new introduction is the Trumbull, a pure-line selection of the Fultz. Wherever the Fultz wheat is found satisfactory, the Trumbull should succeed. It may be expected to yield 2 to 4 bushels per acre more than the Fultz. It possesses the quality of all pure lines—greater uniformity than the bulk seed, is fair in bread making, and among the good ones in stiffness of straw (205, p. 466).

Distribution.—Grown in Crawford, Monroe, and Pickaway Counties, Ohio.

FULTZO-MEDITERRANEAN.

Description.—Plant winter habit, midseason, midtall; stem purple, strong; spike awnless, clavate, dense, erect; glumes glabrous, white, midlong, midwide,

easily shattered; shoulders wanting to narrow, oblique; beaks wide, obtuse, 1 mm. long; apical awns several, 1 to 10 mm. long; kernels red, short to mid-long, soft, ovate; germ midsized; crease narrow to midwide, shallow to mid-deep; cheeks usually rounded; brush midsized, midlong.

This variety is very distinct from Fultz in having very strong stems and erect, dense, clavate spikes.

Spikes, glumes, and kernels are shown in Plate XIX, B.

History.—The origin of Fultzo-Mediterranean is not definitely known. Many synonyms are used for the variety, one of which may be the original name. The variety was first distributed as Fultzo-Mediterranean by Everitt's O. K. Seed Store, Indianapolis, Ind., in 1898. The variety was evidently named by that firm, and it is claimed by them to have originated from a cross between Fultz and Mediterranean. The following statement concerning its origin was made in their catalogue in 1899 (89, p. 8):

MARRIED.—Two Noble Old Families Joined in Wedlock—Mr. Fultz to Miss Mediterranean. Their first-born is well named, Fultzo-Mediterranean, and is a worthy offspring from Noble Stock.

Fultzo-Mediterranean shows no indication of having been derived from Mediterranean, although it has many of the characters of Fultz. Neither of the alleged parents has the clavate spike of the Fultzo-Mediterranean.

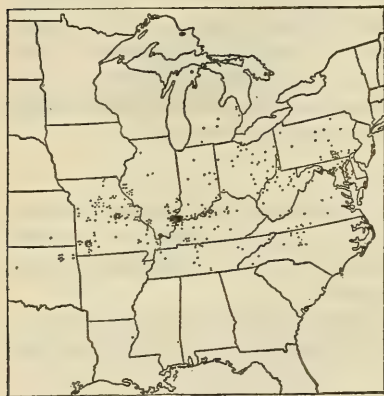


FIG. 32.—Outline map of a portion of the eastern United States, showing the distribution of Fultzo-Mediterranean wheat in 1919. Estimated area, 287,900 acres.

Distribution.—Grown in Delaware, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Missouri, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Virginia, and West Virginia. The distribution is shown in Figure 32.

Synonyms.—Burrhead, Club, Club Head, Columbia, Double Head, Duck Bill, Early Ontario, Economy, Farmers Pride, Flat Top, Four-Row Fultz, Harper, New Columbia, Scott's Squarehead, Square Head, Square Top, and Stub Head. Of these, the names Burrhead, Club, Club Head, Double Head, Duck Bill, Flat Top, Square Head, Square Top, and Stub Head are names used for Fultzo-Mediterranean in several of the Eastern States, particularly North Carolina, Vir-

ginia, and West Virginia. In that section it is often wrongly referred to as Club wheat. The names Columbia and New Columbia are known to be old names for the variety. In fact, the latter name was used for the variety by Everitt in the same year he first distributed it as Fultzo-Mediterranean and evidently also before that time, as the following quotation is from the same catalogue as the quotation given above:

An Illinois production and first made public the year of the great World's Fair. Too much can not be said in its praise for hardiness, vigorous growth, and productiveness. In short, it has great merit and is entitled to be called our national wheat, as it bears our national name. Smooth head, white chaff, plump red grains. Wherever sown it makes friends. (89, p. 11.)

New Columbia was reported grown in Illinois, Indiana, Kentucky, Missouri, North Carolina, Ohio, and Tennessee.

Early Ontario is the name under which wheat similar to Fultzo-Mediterranean was obtained from the Ohio Agricultural Experiment Station in 1916.

A wheat of unknown characters was obtained under that name by the United States Department of Agriculture in 1902 from William Rennie, seedsman, of Toronto, Canada. Early Ontario was not reported in our varietal survey. Economy is a name used on farms for Fultzo-Mediterranean, as well as for the Fultz variety. Farmers Pride is a local name used for Fultzo-Mediterranean in Missouri.

Four-Row Fultz is a name under which Fultzo-Mediterranean was advertised and sold by A. H. Hoffman, seedsman, of Landisville, Pa. Our sample from that source was obtained in 1913. Four-Row Fultz was reported grown in Pennsylvania.

Scott's Squarehead is the name under which a sample of wheat similar to Fultzo-Mediterranean was obtained from the Kansas Agricultural Experiment Station in 1916. Its further history is undetermined and it was not reported in the survey.

KINNEY.

Description.—Plant spring habit, late, midtall; stem very glaucous before maturity, white, strong; spike awnless, oblong, middense, erect to inclined; glumes glabrous, white, midlong, wide; shoulders midwide, oblique to square; beaks wide, acute, 1.0 mm. long; apical awns several, 3 to 20 mm. long; kernels red, usually short, soft, broadly ovate, humped; germ mid-sized; crease midwide to wide, shallow to middeep; cheeks usually angular; brush mid-sized, midlong.

This variety is distinct from most others in being very glaucous during its growing period. It is a hardy spring wheat and is grown from both fall and spring seeding in the Willamette Valley of Oregon.

History.—According to H. Barendrick, of the Albina Fuel Co., Portland, Oreg., Kinney wheat was introduced into the Willamette Valley of Oregon from France in the late sixties or early seventies by Albert Kinney, son of Robert Kinney, who operated a flour mill in that section. Albert Kinney was selling flour for his father in France, and introduced the wheat, which later became known as Kinney, because he thought that it would be a better milling wheat than the varieties then grown in the Willamette Valley. This did not prove to be the case, however, and many people found fault with the miller later when the wheat was found to be of rather inferior milling quality and brought a slightly lower price than White Winter, the variety most commonly grown. Nothing is known concerning the French name for the Kinney variety.

Distribution.—Grown in Benton, Lane, Linn, Marion, Polk, and Washington Counties, Oreg.

Synonyms.—Noah Island, Odessa, Surprise. These are names recorded by Hyslop (126, p. 674) as synonyms used for Kinney wheat in the Willamette Valley of Oregon.

PURPLESTRAW.

Description.—Plant spring habit, early, midtall; stem purple, midstrong; spike awnless, fusiform, middense, inclined to nodding; glumes glabrous, white, short to midlong, midwide; shoulders narrow to midwide, oblique to square; beaks wide, obtuse, 0.5 to 1.0 mm. long; apical awns several, 3 to 10 mm. long; kernels red, short to midlong, soft, ovate or sometimes nearly oval; germ mid-sized; crease midwide, shallow to middeep; cheeks usually rounded; brush small to mid-sized, midlong.

This variety is fairly hardy and has been grown from fall sowing in the Southeastern States for many years. Its principal advantage over other varieties in that section is its early maturity, which in part is due to its spring habit. Plate XVIII, *B*, shows spikes, glumes, and kernels of this variety.

History.—The origin of Purplestraw wheat is undetermined. It is, however, one of the earlier varieties of wheat grown in the United States. Concerning its early culture, the following information has been recorded by Edmund Ruffin:

From 1822 to the present time the same kind of wheat has been cultivated, first known as Mountain Purplestraw and more lately designated Early Purplestraw (161, p. 103).

As the variety has continued to be an important wheat in the southeastern United States, its successful culture has continued about 100 years.

Distribution.—Grown in Alabama, Arkansas, Connecticut, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. The distribution is shown in Figure 33.



FIG. 33.—Outline map of the southeastern United States, showing the distribution of Purplestraw wheat in 1919. Estimated area, 273,800 acres.

Synonyms.—Alabama Bluestem, Bluestem, Early Purplestraw, Georgia Bluestem, Georgia Red, Mountain Purplestraw, and Ripley.

Alabama Bluestem is a name commonly used for Purplestraw wheat in Alabama. Bluestem is the general name used as a synonym for Purplestraw by many growers of the variety in the Southeastern States. Early Purplestraw is a name, as indicated above, which was formerly used for the variety. In recent years,

however, the word "early" has been dropped, and Purplestraw has become the name most generally used. Georgia Bluestem and Georgia Red are names commonly used by growers of Purplestraw wheat in Georgia. Mountain Bluestem, as stated above, was the name under which the variety was first grown. This name is still used in some sections, although the prefix "Mountain" has generally been dropped for many years. Ripley is a local name used for Purplestraw in York County, S. C.

HUSTON.

Description.—Plant spring habit, early, midtall; stem faintly purple, midstrong; spike awnless, oblong, dense, erect; glumes glabrous, white, midlong, midwide, easily shattered; shoulders wanting to narrow, oblique; beaks narrow, obtuse, 1.0 to 1.5 mm. long; apical awns several, 3 to 10 mm. long; kernels red, short, soft to semihard, broadly ovate; germ mid-sized; crease midwide, shallow to middeep, usually pitted; cheeks rounded, brush small, midlong, sometimes collared.

This is one of the few soft red spring-wheat varieties grown in the United States.

History.—According to S. L. Williams, of the Eugene Mill & Elevator Co., Eugene, Oreg., the variety was introduced in the vicinity of Eugene in 1876 by

a Mr. Belshaw, who obtained a sample of the wheat at the Centennial Exposition, where it was on exhibition as Bulgarian Red Spring. He sowed the few kernels in his garden and in this way obtained sufficient seed to sow 5 acres. His land was low and heavy, however, and the wheat did not prove satisfactory, so he gave the seed to a Mr. Huston living 16 miles west on the hill lands, who grew it with splendid success and the wheat came to be known as Huston.

Distribution.—Grown in Benton, Douglas, Lane, Linn, Marion, Polk, and Yamhill Counties, Oreg.

Synonyms.—Bulgarian, Early Wonder, Grass, Little Red, Ninety-Day, Red Spring, and Swamp.

Bulgarian, as indicated above, was the name under which the variety was known before it was introduced in Oregon, and the name is still used in Linn County, Oreg. Early Wonder was recorded by Hyslop (126) as a synonym for Huston and is much used for the Huston variety in Benton, Linn, and Polk Counties, Oreg. Grass, Little Red, Ninety-Day, Red Spring, and Swamp are also local names used for Huston by farmers in the Willamette Valley of Oregon.

ALTON (GHIRKA WINTER).

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awnless, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks wide, acute, 1 mm. long; apical awns few, 3 to 10 mm. long; kernels red, usually short, hard, ovate; germ very small; crease narrow to midwide, shallow; cheeks rounded; brush mid-sized, midlong.

This variety is the only awnless hard red winter wheat grown commercially in the United States. It usually yields somewhat less than Turkey and its milling and bread-making value is also slightly less than that of Turkey.

History.—Alton was introduced by the United States Department of Agriculture (197) as Ghirka Winter in December, 1900, from Altonau, near Melitopol in northern Taurida, Russia (S. P. I. No. 5637). It was one of a large number of wheat varieties introduced by M. A. Carleton, department cerealist, who went to Russia and Siberia in 1898 and again in 1900 for the purpose of obtaining cereal crops.

This variety proved best adapted in Wyoming and Colorado, where it has been distributed in a small way. The name Alton is here substituted for Ghirka Winter to avoid confusion with the variety of spring wheat known as Ghirka Spring. The name Alton is derived from Altonau, the original source of the sample.

Distribution.—Grown as Ghirka Winter to a limited extent in Colorado, Kansas, and Wyoming.

RED BOBS.

Description.—Plant spring habit, early, midtall; stem white, strong; spike awnless, fusiform, middense, erect; glumes glabrous, white to yellowish, midlong, midwide; shoulders wide, oblique to square; beaks wide, acute, 0.5 mm. long, sometimes nearly wanting; apical awns entirely wanting; kernels red, usually short, hard, oval to ovate, with truncate tip; germ mid-sized; crease midwide to wide, middeep to deep; cheeks angular; brush mid-sized, short.

This variety has two types of plants, but differs from Bobs principally in having red kernels. In the northern spring-wheat sections of the United States Red Bobs has proved very susceptible to stem rust. Spikes, glumes, and kernels of the variety are shown in Plate XX, A.

History.—The Red Bobs originated from a head selection made in a field of Bobs wheat by Seager Wheeler in 1910 at Maple Grove Farm, Rosthern, Sas-

katchewan. It was distributed for the first time in 1918, and its history was recorded the following year by Mr. Burns in the *National Alfalfa Journal* (55). A fuller history of this variety has been recorded by Buller (50, p. 259-275). It is evidently the result of a natural field hybrid between Bobs and a red-kernelled variety.

Distribution.—Grown at several experiment stations in the northwestern United States and commercially in Canada and probably to a limited extent in the Dakotas and Minnesota in 1920, as the seed has been advertised for sale for three years. It was not reported in the varietal survey.

MARQUIS.

Description.—Plant spring habit, early, short to midtall; stem white, strong; spike awnless, fusiform, dense, erect; glumes glabrous, white to yellowish, short, wide; shoulders midwide to wide, usually square; beaks wide, acute, 0.5 mm. long; apical awns few, 1 to 10 mm. long; kernels red, short, hard, ovate, with truncate tip; germ mid-sized; crease wide, deep; cheeks angular; brush mid-sized, midlong.

This is a high-yielding spring wheat, and it is one of the best varieties for milling and bread making. Its high yield and popularity are due principally to its early maturity, which has sometimes enabled it to escape stem rust and drought. Spikes, glumes, and kernels are shown in Plate XXI, A.

History.—Marquis is of hybrid origin, having been originated by the cerealists of the Dominion Department of Agriculture at the Central Experimental Farm, Ottawa, Canada. The crossing which resulted in the origin of Marquis was done under the direction of Dr. William Saunders, former Dominion cerealist. To the present Dominion cerealist, Dr. C. E. Saunders, the credit for originating (selecting, naming, testing, and distributing) the variety is due. He has given an account of its origin in the following words (167, p. 118-120):

All the details in regard to the origin of Marquis are not available, but it is one of the descendants of a cross between an early-ripening Indian wheat, Hard Red Calcutta (as female) and Red Fife (as male). The cross (as appears from unpublished notes) was made by Dr. A. P. Saunders, probably at the experimental farm at Agassiz, in the year 1892. The crossbred seeds, or their progeny, were transferred to Ottawa and when the writer of this report was appointed in 1903 to take charge of the work of cereal breeding he made a series of selections from the progeny of all the crossbred wheats which had been produced at Ottawa up to that time. Some of these had been named and others were under numbers. Though they had all been subjected to a certain amount of selection, each of them consisted of a mixture of related types. In some cases all the types present were similar. In other instances striking differences were observed. The grain which had descended from the cross referred to above was found by careful study of individual plants (especially by applying the chewing test to ascertain the gluten strength and probable bread-making value) to be a mixture of similar looking varieties which differed radically in regard to gluten quality. One of the varieties isolated from this mixture was subsequently named Marquis. Its high bread-making strength and color of flour were demonstrated in the tests made at Ottawa in the early months of 1907, and all the surplus seed was at once sent to the Indian Head Experimental Farm for propagation.

It will be clearly seen from the above account that the question, "When was Marquis wheat originated?" can never be answered. It came into existence probably at Ottawa between the years 1895 and 1902. It remained, however, mixed with other related sorts until discovered by the writer in 1903. It was first grown in a pure state in 1904, when a few seeds were sown in a sheltered garden on the Central Experimental Farm. Even then, however, its fine qualities were only partly known, and it was not until the cerealist's baking tests of 1907 were completed that he decided to send out this wheat for trial in Saskatchewan. Its success in the prairie country was phenomenal.



RED BOBS (A).

KITCHENER (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



MARQUIS (A).

RED FIFE (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

Marquis wheat was first sent to the Prairie Provinces of Canada in 1907, where it was thoroughly tested at experiment stations. At Indian Head and Rosthern, Saskatchewan, and at Brandon, Manitoba, it very significantly out-yielded all other varieties. By 1911 the variety had become commercially established in Canada.

Attention was first attracted to Marquis wheat in the United States through its having won premiums at several expositions. Seed was introduced by the United States Department of Agriculture in 1912 and 1913, and the variety was thoroughly tested at numerous experiment stations in the spring-wheat sections. These and other experiments, reported by Ball and Clark (40, 41), proved the variety to be widely adapted. In the meantime, in consequence of much publicity, a strong demand for seed arose. A considerable quantity was brought into the country for sowing in 1913. Much larger quantities were imported in 1914. The importations of these two years, with the seed home

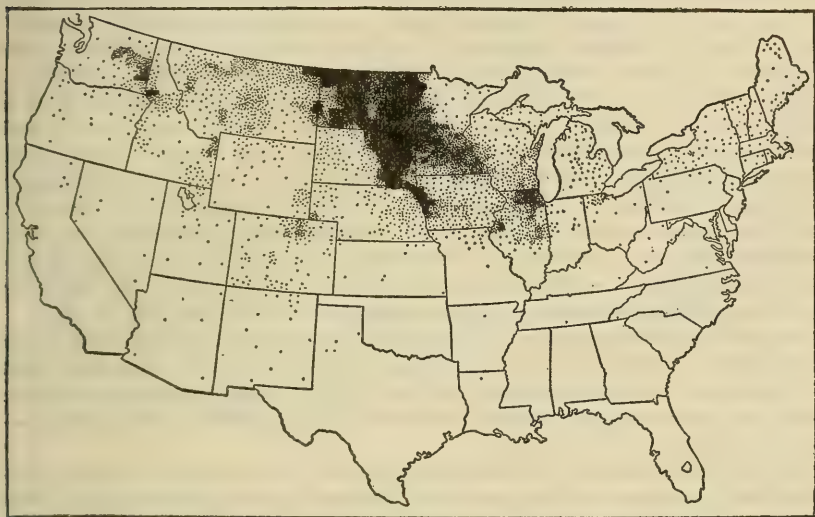


FIG. 34.—Outline map of the United States, showing the distribution of Marquis wheat in 1919. Estimated area, 11,825,200 acres.

grown in 1913, were sufficient to sow about half a million acres in 1914. Most of the imported seed was sold in Minnesota, North Dakota, and Montana. Smaller quantities were sold in other spring-wheat States. In this way the Marquis variety became widely distributed in a very short time. In 1919, only seven years after its introduction, it made up at least 60 per cent, or nearly 12,000,000 acres, of the total spring-wheat acreage of the United States.

Distribution.—Grown in Arizona, Arkansas, California, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Vermont, Washington, West Virginia, Wisconsin, and Wyoming. This wide distribution is due partly to emergency conditions, because of the World War. Normally spring wheat is not so widely grown. The distribution of Marquis wheat in 1919 is shown in Figure 34.

RED FIFE.

Description.—Plant spring habit, midseason, midtall; stem white, strong; spike awnless, fusiform, middense, erect to inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks narrow, acute, 0.5 to 1.0 mm. long; apical awns few, 2 to 5 mm. long; kernels red, short to midlong, hard, ovate; germ mid-sized; crease wide, deep; cheeks angular; brush mid-sized, midlong.

This variety differs from Marquis in being taller and later, with kernels slightly longer and more pointed. It is a fairly good yielder and an excellent milling and bread-making wheat. Spikes, glumes, and kernels of Red Fife wheat are shown in Plate XXI, B.

History.—Red Fife wheat was introduced into the United States from Galicia, by way of Germany, Scotland, and Canada. Several conflicting stories of its introduction have been written. The most authentic story is that, about 1842, David Fife, of Otonabee, Ontario, Canada, received a small sample of wheat from a friend in Glasgow, Scotland. The friend had obtained the sample from a shipload of wheat from the port of Danzig in Germany, but supposedly of Russian origin. Mr. Fife sowed the wheat in the spring, but it proved to be a winter wheat. A plant of spring wheat developed, however, which was saved and increased. From it descended the wheat which became known as Red Fife throughout Canada. The details of this introduction and several interesting traditions concerning it have been fully recorded by Buller (50, p. 206-218). That the original seed of Red Fife wheat probably came from Galicia has been established by two other identical introductions, one by the Canadian Department of Agriculture in 1904 (165, p. 216-217), and another (C. I. No. 2463) by the United States Department of Agriculture in the same year (39, p. 11).

The cultivation of Red Fife wheat in the United States dates from 1860, when J. W. Clarke, a Wisconsin farmer, had an excellent crop (68). The name Red Fife was never commonly adopted, the word "Fife" being the name most often used. As the wheat increased in popularity and cultivation, other names became applied to it.

Many growers selected and distributed the Red Fife wheat and usually prefixed their own name to the name Fife. Among these are the following: Bernard Fife, Herman Fife, McKendry Fife, McKissick Fife, Pillsbury Fife, Verdon Fife, and Wilcox Fife. Wheats once known under these names have long since disappeared from culture.

Distribution.—Grown as Fife in Idaho, Illinois, Iowa, Maine, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New York, North Dakota, Oklahoma, Oregon, Pennsylvania, South Dakota, Utah, Vermont, Wisconsin, and Wyoming. This distribution combined with that of the Power and Glyndon varieties is shown in Figure 35.

Synonyms.—Canadian Fife, Fife, Saskatchewan Fife, Scotch Fife. Canadian Fife and Scotch Fife are names which were early used for the Red Fife wheat in the United States. Both these names have continued in use until the present time.

Saskatchewan Fife is a selected strain of Red Fife distributed by D. L. Wellman, of Frazee, Becker County, Minn., in 1878. Mr. Wellman received a pint package of Red Fife wheat from W. J. Abernethy, agricultural editor of the Pioneer Press, St. Paul, Minn. He grew this wheat for a number of years and selected it carefully, roguing out all mixtures. In the fall of 1883 he had a stock of 1,300 bushels which he put on the market as Saskatche-

wan Fife (201). This wheat in a few years became well known and quite widely grown and is still in cultivation. It was reported grown in New Jersey, Pennsylvania, and South Dakota.

POWER.

Description.—Power is slightly shorter and has a more erect spike than Red Fife, and the kernels are slightly shorter. A spike of Power wheat is shown in Plate VI, Figure 3.

History.—Power is a pure-line selection of Red Fife wheat which was started about 1885 by James Holes, of Fargo, N. Dak., from a single plant of Red Fife wheat found growing in an oat field (39, p. 11). Some of this seed was obtained by J. B. Power, of Power, N. Dak., who increased it and distributed it in large quantities under the name of Power Fife. This strain was grown by the North Dakota Agricultural Experiment Station and known



FIG. 35.—Outline map of the United States, showing the distribution of Red Fife wheat in 1919. Estimated area, 750,000 acres.

as Station No. 66. A number of pure-line selections were made from it at the North Dakota Experiment Station in 1892. One of these pure lines, known as North Dakota No. 313 (C. I. No. 3697), has been called Power, and is the strain now most commonly grown. In experiments at the Williston substation, Williston, N. Dak., it proved to be a high-yielding wheat for that section, and seed was recently increased and distributed in the vicinity of that station.

Distribution.—Grown in Montana and North Dakota.

Synonyms.—Power's Fife, Station No. 66.

GLYNDON.

Description.—Plant spring habit, midseason, midtall to tall; stem white, midstrong; spike awnless, fusiform, middense to lax, inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks narrow, acute, 0.5 to 1.0 mm. long; apical awns few, 3 to 15 mm. long; kernels red, midlong, hard, ovate; germ mid-sized; crease wide, deep; cheeks angular; brush mid-sized, midlong.

Glyndon differs from Red Fife and Power principally in having longer and laxer spikes. Spikes, glumes, and kernels of Glyndon wheat are shown in Plate XXII, A.

History.—This strain of Fife wheat dates from about 1891, when it was first grown by the Minnesota Agricultural Experiment Station as No. 811, at the Glyndon farm in western Minnesota. In the burning of the Glyndon station buildings all records of its origin were lost. Without doubt, however, it is one of the many samples of Red Fife wheat obtained from Minnesota farmers in 1888 and 1889. In 1892 the breeding of eight of the best varieties of wheat which had been selected by the Minnesota station was begun by continuous selection, known as the centgener system, by W. M. Hays, then at the North Dakota Agricultural Experiment Station. Four hundred selected kernels of the eight varieties which had been grown at Glyndon, Clay County, in the previous year were sown at Fargo, N. Dak., and a like number on the farm belonging to J. B. Power & Sons, of Power, Richland County, N. Dak. Some of these selections were from No. 811. All of the selections were grown at Fargo again in 1893. From the 400 selected kernels, 31 plants having the largest yield and of superior quality were chosen for seed the next season. In 1893, 100 to 400 kernels from each of these 31 plants were sown at Fargo in a manner similar to the method used in 1892. In 1893, the best plant was chosen from the progeny of each of the 31 plants above mentioned. One selection made that year from No. 811 was accessioned as Minnesota No. 163. This selection, with many others, was sown at the University Farm, St. Paul, Minn., in 1894, in a small plat. In 1895 and 1896, 31 strains were tested at University Farm, and 8 were selected and grown at other stations. Among them was Minnesota No. 163. After further testing, this strain was selected as the best of the Fife types and seed was increased and distributed to farmers in 1898 (109, p. 105). It was first distributed as Minnesota No. 163, but in 1915 the name Glyndon was assigned to it by the Minnesota station.

Distribution.—Grown in Minnesota, North Dakota, and South Dakota. It is grown most in Minnesota, where it was once an important wheat. In recent years, however, it has largely disappeared from culture.

Synonyms.—Minnesota No. 163. As indicated above, this is the Minnesota accession number which was used as a name for the variety from 1898, when it was first distributed, until 1915, when it was named Glyndon.

RYSTING.

Description.—Rysting is a strain of Fife wheat apparently identical with Glyndon. It has not yielded as well as Glyndon in some sections, while in others it has done as well or better.

History.—Rysting was selected, increased, and distributed about 1892 by Jens Rysting, of Buxton, N. Dak. (39, p. 12). Mr. Rysting claimed that it was earlier than the ordinary Red Fife.

Distribution.—This strain is still grown in experiments at several stations in the northern spring-wheat area and probably commercially in North Dakota. Its commercial distribution, however, can not be separated from that reported for other Fife wheats.

Synonym.—Rysting's Fife.

WELLMAN (WELLMAN'S FIFE).

Description.—Plant spring habit, midseason, midtall to tall; stem white, mid-strong; spike awnless, linear-fusiform, lax (68 to 75 mm. per 10 nodes) in-



GLYNDON (A).

WELLMAN (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



DAWSON (A).

GOLDCOIN (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

clined, long (8 to 13 cm.) ; glumes glabrous, white, midlong, midwide ; shoulders midwide, oblique to square ; beaks narrow, acute, 1 mm. long ; apical awns few, 3 to 6 mm. long ; kernels red, short, semihard, ovate, with truncate tip ; germ midsized ; crease wide, deep ; cheeks angular ; brush midsized, midlong.

Wellman differs from Red Fife and Glyndon in being slightly taller and having a much longer and laxer spike and a shorter and softer kernel. Plate XXII. B, shows spikes, glumes, and kernels of this variety.

History.—Wellman (Wellman's Fife) wheat was developed by D. L. Wellman, of Frazee, Becker County, Minn., from a plant selected out of Red Fife wheat which he called Scotch Fife, the original sample having been obtained from the "Saskatchewan Valley" in Canada. The original sample was a mixture. Several strains from it were grown, and this strain, which was taller and had a much longer and laxer spike, was increased and distributed for the first time, in the spring of 1884, as Wellman's Fife (20). A variety called White Russian was grown by the Colorado Agricultural Experiment Station (46, p. 40) as early as 1879 and by the Indiana Agricultural Experiment Station in 1884 (136, p. 54). It was grown in varietal experiments at Indian Head, Saskatchewan, for the first time in 1891, while Wellman's Fife was grown at the same station the year previous. The two varieties are identical and have always been considered as synonymous in Canada. It is probable that Mr. Wellman only selected a chance head of this White Russian wheat from his Canadian mixture.

Distribution.—Wellman's Fife was quite widely grown in the northern Great Plains and Minnesota and in the New England States and New York during the nineties, but since has practically disappeared from cultivation. It was reported from Aroostook County, Me.

Synonyms.—Saskatchewan Fife and White Russian. Saskatchewan Fife was advertised during the nineties as a synonym of Wellman's Fife by Peter Henderson & Co., seedsmen, of New York City (110). As indicated above, White Russian is an older name for this variety than Wellman and is still used in Canada.

EARLY RED FIFE.

Description.—Plant spring habit, early to midseason, midtall ; stem usually white, sometimes showing a faint tinge of purple, strong ; spike awnless, linear-oblong, sometimes becoming subclavate ; middense, erect ; glumes glabrous, yellowish white, midlong, narrow to midwide ; shoulders wanting to narrow, oblique ; beaks narrow, obtuse, 1 mm. long ; apical awns several, 3 to 30 mm. long ; kernels red, midlong, hard, ovate ; germ midsized ; crease midwide to wide, shallow to deep ; cheeks angular ; brush midsized, midlong.

Early Red Fife differs from other Fife strains in being earlier and in having a linear-oblong instead of a fusiform spike. The kernels also have a somewhat shallower crease.

History.—This is an early-ripening selection of Red Fife wheat, made and developed by Dr. C. E. Saunders, Dominion cerealist, at the Central Experimental Farm, Ottawa, Canada, where it has been grown since 1908 (166, p. 202-203).

Distribution.—Grown commercially in Canada and experimentally in Montana and North Dakota.

GHIRKA (GHIRKA SPRING).

Description.—Plant spring habit, early, midtall ; leaves pubescent ; stem glaucous when immature, usually purple, sometimes only faintly so, midstrong ; spike awnless, linear-fusiform, middense, inclined to nodding ; glumes glabrous, white, long, narrow ; shoulders wanting to narrow, oblique ; beaks narrow, acute, 1 mm. long ; apical awns few, 3 to 6 mm. long ; kernels pale red, midlong, semi-

hard, ovate to elliptical, slightly humped, acute; germ small to midsized; crease midwide to wide, middeep to deep; cheeks usually angular; brush small, mid-long.

This variety differs from the true Fife strains in having a longer and more tapering spike and larger and softer kernels. It is a high-yielding, drought-resistant wheat, but is inferior to Fife strains for milling and bread making. A spike of this variety is shown in Plate V, Figure 1.

History.—Ghirka (Ghirka Spring) was an important variety in Russia, grown principally in southern Russia and the Volga River district. It was introduced into the United States several times during the period from 1898 to 1904, inclusive, eight lots having been imported by the United States Department of Agriculture. Other importations were made by Russian immigrants. Joseph Dukart, who settled at New England, N. Dak., brought a 2-pound lot from Russia in 1905. From the increase of this, several thousand acres were grown in western North Dakota from 1914 to 1916 (65, p. 2).

Distribution.—Grown sparingly, mostly under the name Russian, in North Dakota, South Dakota, Vermont, and Wyoming.

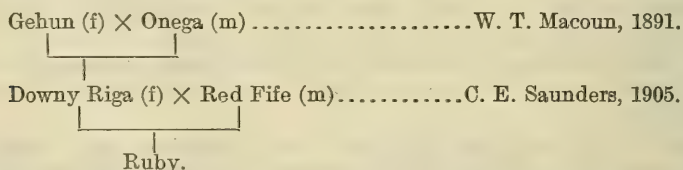
Synonyms.—Early Russian, Russian, and Russian Fife. The name Early Russian has long been used for Ghirka wheat in Canada. Russian and Russian Fife are names used by Russian settlers who grow the wheat in western North Dakota and South Dakota.

RUBY.

Description.—Plant spring habit, early, short; stem purple, strong; spike awnless, oblong-fusiform, dense, erect; glumes glabrous, yellowish white, short, midwide; shoulders wide, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns several, 3 to 10 mm. long; kernels red, short, hard, ovate; germ midsized to large; crease midwide to wide, shallow to deep; cheeks angular; brush midsized, short.

Ruby differs from Marquis principally in being about five days earlier and in having purple straw. In preliminary experiments in the United States it has not compared favorably with Marquis in yield, but has equal milling and bread-making value.

History.—The Ruby variety was originated by Dr. C. E. Saunders, Dominion cerealist, at the Central Experimental Farm, Ottawa, Canada, and was distributed for the first time in 1917. The parentage of Ruby has been recorded by Buller (50, p. 186) as follows:



Distribution.—Grown at several experiment stations in the northern spring-wheat sections of the United States since 1918 and commercially since 1920.

KITCHENER.

Description.—Plant spring habit, early to midseason, midtall to tall; stem purple, strong; spike awnless, oblong to subclavate, middense, erect; glumes glabrous, yellowish white, short, wide; shoulders midwide, oblique to square; beaks midwide, acute, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels

red, short, hard, ovate, with truncate tips; germ mid-sized; crease wide, mid-deep; cheeks angular; brush mid-sized, mid-long.

Kitchener differs from Marquis in being taller and later and in having a broader spike, purple straw, and a slightly longer and more rectangular kernel. (Plate XX, B.)

History.—This variety originated from a head selected in a field of Marquis by Seager Wheeler in 1911 at Maple Grove Farm, Rosthern, Saskatchewan. It was increased and tested for yield by Mr. Wheeler for a period of four or five years and then distributed (202).

Distribution.—Grown at several experiment stations in the spring-wheat sections of the United States and commercially in Canada.

CLIMAX (JONES CLIMAX).

Description.—Plant winter habit, mid-season to late, tall; stem white, mid-strong; spike awnless, linear-fusiform, lax, nodding; glumes glabrous, white, mid-long to long, mid-wide; shoulders wanting to narrow, oblique; beaks wide, obtuse, 1 mm. long; apical awns few, 3 to 10 mm. long; kernels red, mid-long to long, soft, elliptical to ovate; germ mid-sized; crease mid-wide, mid-deep; cheeks usually rounded; brush mid-sized, mid-long.

This variety is very distinct because of its long, lax, tapering, and nodding spike. Spikes, glumes, and kernels of this wheat are shown in Plate XVII, B.

History.—The origin of Climax (Jones Climax) is not definitely determined. It is very similar to the Celebrated K. B. No. 2 variety, differing only in having a more nodding spike. The latter wheat was distributed by the Knight & Bostwick Seed Co., Rochester, N. Y., who have given its history as follows:

During the summer of 1898 we discovered growing in our field of Long Berry Clawson . . . a single head of wheat that showed qualities distinctly superior to its celebrated parent. . . . We sowed it in our trial grounds . . . called it our Celebrated K. B. No. 2 (122, p. 90).

Its distribution dates from 1902, although it apparently did not become widely grown. This or a very similar wheat evidently was rather recently named Jones Climax and distributed by Everitt's O. K. Seed Store, Indianapolis, Ind., and the commercial distribution of the variety was thus established. There seems to be no evidence that A. N. Jones, of New York, who developed several varieties of wheat, had anything to do with this variety.

Distribution.—Grown as Jones Climax in Georgia, Illinois, Indiana, Kentucky, Missouri, North Carolina, and West Virginia, and under the names of synonyms in Pennsylvania. The distribution is shown in Figure 36.

Synonyms.—Celebrated K. B. No. 2, Grecian, K. B. No. 2, Pennsylvania Standard, Wilson, and Wilson Special. As shown above, Celebrated K. B. No. 2 was possibly the original name. Most experiment stations grew and recorded it simply as K. B. No. 2. Grecian is a name used for the variety in Butler County, Pa., where it has been grown for about 10 years. Pennsylvania Standard is a name used for the variety in Schuylers County, Mo., where, according to W. J. Ford, of Glenwood, it has been grown for about 25 years and now



FIG. 36.—Outline map of the east-central United States, showing the distribution of Climax wheat in 1919. Estimated area, 16,800 acres.

constitutes 25 per cent of the wheat grown in the vicinity. Wilson and Wilson Special are names used for the variety in Marion County, Ind., and Lycoming County, Pa.

KOFOD.

Description.—Plant usually winter habit, sometimes intermediate or spring, midseason, midtall; stem white, slender, weak; spike awnless, fusiform, mid-dense, nodding; glumes glabrous, yellowish, brown streaked, midlong, midwide; shoulders midwide, usually oblique to square but sometimes more variable; beaks usually wide, obtuse, 1 mm. long; apical awns few, 2 to 15 mm. long; kernels white, midlong, soft, ovate, acute; germ small to midsized; crease midwide, middeep; cheeks angular; brush midsized, midlong.

The characters of Kofod wheat are rather variable and unstable. The kernel is extremely soft.

History.—An interesting but probably mythical story regarding the origin of Kofod wheat was published in the *Deseret Farmer* in 1906 (29). According to the story, Amasa Potter, of Payson, Utah, in the year 1870 was exploring ancient mounds in Utah County, near Payson, in one of which he found two skeletons and, among other things, a small quantity of wheat. Most of the grain had decayed, but a few apparently sound kernels remained. These he sowed, and increased and distributed the resulting yield. The published correspondence further shows that he let Orwell Simons, of Payson, Utah, have some of the seed, and he in turn let Peter Winward, of the same place, have some. A John C. Whitbeck obtained some of the seed from Peter Winward in 1875 and took it to Levan, Utah. Hans C. Kofod, of Levan, later obtained seed of this wheat from Mr. Whitbeck and thus got the start of what is now known as Kofod wheat. The fact that wheat usually loses its viability after 10 or 15 years makes this story of its ancient origin extremely improbable.

Distribution.—Grown in Iron, Juab, Millard, and Sanpete Counties, Utah.

Synonym.—Koffoid. This is the name under which this wheat has been grown and referred to in previous publications by the United States Department of Agriculture and by the Utah Agricultural Experiment Station until 1919. The name was changed to Kofod upon learning the correct spelling of Mr. Kofod's name.

DAWSON (DAWSON GOLDEN CHAFF).

Description.—Plant winter habit, midseason, midtall; stem white, strong; spike awnless, linear-oblong, middense, inclined; glumes glabrous, light brown, midlong, wide; shoulders wide, oblique to square; beaks midwide, obtuse, 0.5 mm. long; apical awns few, 3 to 20 mm. long; kernels white, short to midlong, soft, ovate to oval; germ midsized to large; crease midwide to wide, middeep; cheeks usually angular; brush midsized, midlong.

Dawson differs from Goldcoin chiefly in having white straw, an oblong spike, and no collar around the brush. Spikes, glumes, and kernels of Dawson wheat are shown in Plate XXIII, A.

History.—Originated in 1881 by Robert Dawson, of Paris, Ontario, Canada (177, p. 8). It was selected "in a field of Seneca or Clawson, in which he found one plant quite distinct and much superior to the rest of the crop. Mr. Dawson sowed the grain from this plant and has continued to grow this wheat since. It was practically unknown over Ontario until tested at the experimental station along with many old and new varieties and the comparative results published. It has ranked first in yield from the beginning" (178, p. 11).

Distribution.—Grown in Illinois, Indiana, Kentucky, Massachusetts, Michigan, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin. Figure 37 shows the distribution of this variety.

Synonyms.—Golden Bronze, Golden Chaff, Improved Amber, White Winter. Golden Bronze is the name under which a strain of this variety was being grown at the Cornell University Agricultural Experiment Station.

Golden Chaff is simply a shortening of the name Dawson Golden Chaff. Improved Amber is the name under which a sample of Dawson was obtained from the Wisconsin station. White Winter is a local descriptive name used for the variety by farmers.

HONOR.

Description.—Honor apparently is identical with Dawson in all morphological characters, except for a slightly stronger stem. It is more winter resistant and a better yielder.

History.—Honor was originated by the plant-breeding department of the Cornell University Agricultural Experiment Station, in cooperation with the Office of Cereal Investigations, United States Department of Agriculture. During the experimental stages it was known as Cornell Selection 522-68. Concerning the variety, Dr. H. H. Love, who is in charge of the cooperative experiments at Cornell has written¹² as follows:

Honor was selected from Dawson's Golden Chaff and seems to be a typical Golden Chaff. I think it is slightly more winter hardy than the commercial variety and has somewhat stiffer straw.

Distribution.—The selection was distributed from Cornell University to selected farmers for several years previous to the fall of 1920, when it was first offered for sale as Honor wheat by C. A. Rogers (160), of Bergen, N. Y.

SCHONACHER.

Description.—Plant winter habit, midseason, midtall; stem white, strong; spike awnless, oblong, middense, inclined to nodding; glumes glabrous, brown, midlong, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 mm. long; apical awns several, 2 to 30 mm. long; kernels white, midlong, semihard, ovate; germ mid-sized to large; crease midwide, middeep; cheeks angular; brush mid-sized, midlong.

Schonacher has a harder kernel than Dawson, and the spike is more nodding.

History.—The origin of this variety is undetermined. The variety was obtained from the Cornell University Agricultural Experiment Station, Ithaca, N. Y., in 1917.

Distribution.—Grown by the Cornell University Station. A red-kerneled wheat was reported under this name from Juniata County, Pa.

ARCADIAN (EARLY ARCADIAN).

Description.—Plant winter habit, midseason, short; stem white, strong, stout; spike awnless, clavate, short, dense, erect; glumes glabrous, brown, midlong, wide; shoulders midwide, oblique to rounded; beaks wide, obtuse, 1 mm. long; apical awns several, 3 to 10 mm. long; kernels white, usually short, usually soft, broadly ovate; germ mid-sized; crease wide, shallow to middeep; cheeks usually angular; brush small, midlong.

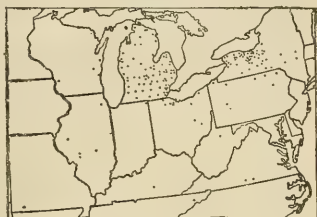


FIG. 37.—Outline map of the north-central United States, showing the distribution of Dawson wheat in 1919. Estimated area, 125,500 acres.

¹² Correspondence of the Office of Cereal Investigations, dated Mar. 19, 1921.

The distinctive characters of the Arcadian variety are the stiff straw and the extremely clavate spike. A spike of this variety is shown in Plate V, Figure 6.

History.—Originated by A. N. Jones, Newark, Wayne County, N. Y., in 1895, as the result of a direct cross between Early Genesee Giant and Early Red Clawson (61, p. 221).

Distribution.—Grown commercially in Yakima and Klickitat Counties, Wash., in 1916. Not reported from New York, where it was first distributed.

WINDSOR (EXTRA EARLY WINDSOR).

Description.—Plant winter habit, early to midseason, short to midtall; stem purple, midstrong; spike awnless, fusiform, middense, nodding; glumes glabrous, brown, midlong, midwide; shoulders wanting to narrow, rounded to oblique; beaks narrow, obtuse, 0.5 mm. long; apical awns few, 5 to 10 mm. long; kernels white, midlong, soft, broadly ovate; germ mid-sized to large; crease midwide, shallow to middeep; cheeks usually angular; brush small, midlong.

Windsor differs from Goldcoin chiefly in having an oblong, nodding spike.

History.—The origin is undertermined. It was grown by the Ohio Agricultural Experiment Station as early as 1892 (204, p. 52).

Distribution.—Grown experimentally by the Ohio and Cornell University (New York) Agricultural Experiment Stations and commercially in Kalamazoo County, Michigan.

GOLDCOIN (GOLD COIN).

Description.—Plant winter habit, early to midseason, short to midtall; stem purple, strong; spike awnless, clavate, middense, erect to inclined; glumes glabrous, brown, long, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 1 mm. long; apical awns several, 5 to 15 mm. long; kernels white, short to midlong, soft, ovate; germ mid-sized; crease midwide, middeep; cheeks usually rounded; brush small, midlong, collared.

The distinctive characters of Goldcoin wheat are the purple straw, clavate spike, and collared brush. Spikes, glumes, and kernels of this variety are shown in Plate XXIII, B.

History.—The Goldcoin variety is probably a descendant from the Redchaff or Redchaff Bald wheat mentioned in early agricultural literature as being grown in the Genesee Valley of New York, as early as 1798. The following history of Redchaff was recorded by Allen (36, p. 153) in 1885.

The old Genesee Redchaff is a bald, white wheat, first cultivated in the same region in 1798, and for a long time it was the decided favorite. Since 1820, however, it has been very subject to rust and blast, but when circumstances are favorable it is still found to be highly productive. Its transfer to other localities may therefore be attended with great success.

Soules is an early name applied to a wheat apparently identical with Goldcoin. The following statement concerning the origin of Soules was recorded by Harnnon (103, p. 225) in 1843:

In the first volume of the New Genesee Farmer (2) this new wheat was noticed as being discovered, or a few heads being found, in a field of White Flint by Jonathan Soule, of Perrington, Monroe County.

This wheat became well established in New York in the late forties, and by 1857, according to Klippart, (131, p. 755-756), was an important variety in Ohio. About 1897 this wheat or a selection from it became known as New Soules. Soules and White Soules were reported in 1919 from Michigan.

This variety originated in Seneca County, N. Y., in 1865, through the selection of certain superior heads from a field of Fultz by Garrett Clawson. On planting the grain from these heads, both a white and red grained sort resulted the following season. The white wheat was considered the best, and the pint of seed obtained of this sort was sown, producing 39 pounds the following season. The third year after this 254 bushels were harvested and that season the variety was distributed to other farmers. In 1871 this variety took first premium at the Seneca County fair, and in 1874 seed was distributed by this Department. Though judged inferior by millers at times, this variety has become a very popular one. It must not be confused with Early Red Clawson, a very distinct variety.

Mr. Green grew a field of Diehl Mediterranean, a bearded, red-grained wheat, and while passing through the field one day found a bald head possessing white grains. Planting every grain of this head, he found as a result next season that he had heads with very long beards, some with short beards, and others with



none at all. The grain also was mixed, some red and some white. He desired the bald wheat—hence only the grains from the bald heads were again planted. From this as a beginning, a practically new variety resulted. Various names have been given to it by different seedsmen, but it is best known by the name Gold Coin.

The commercial production of Goldcoin wheat dates from about 1900.

Distribution.—Grown in California, Colorado, Connecticut, Idaho, Illinois, Indiana, Kentucky, Michigan, Montana, Nevada, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Utah, Virginia, Washington, West Virginia, Wisconsin, and Wyoming. This distribution is shown in Figure 38.

Synonyms.—Abundance, American Banner, Clawson, Eldorado, Fortyfold, Golden Chaff, Gold Bullion, Gold Medal, Goldmine, Improved No. 6, International No. 6, Junior No. 6, Klondike, New American Banner, New Soules, Niagara, Number 6, Oregon Goldmine, Plymouth Rock, Prizetaker, Prize-winner, Rochester No. 6, Soules, Superlative, Twentieth Century, White Century, White Clawson, White Eldorado, White Rock, White Russian, White Soules, White Surprise, and Winter King.

Eldorado, Golden Chaff, Gold Bullion, Gold Medal, Niagara, Goldmine, Oregon Goldmine, Plymouth Rock, Prize Winner, Superlative, Twentieth Century, White Century, White Eldorado, White Russian, and White Surprise are local names for the variety, used chiefly by growers in Michigan.

Abundance is a variety apparently identical with Goldcoin, which was introduced by L. P. Gunson & Co., of Rochester, N. Y., about 1894. Mr. Gunson has stated ¹³ "that this variety came from a new stooling wheat which we purchased from A. N. Jones. One of these crossbred varieties, of which we purchased a small amount, showed two different colors of chaff, and two were separated by hand selection. The Abundance was obtained from one of these selections." It probably was selected from the wheat Mr. Jones called Early White Leader. Abundance was reported in 1919 from Michigan, Tennessee, and West Virginia.

American Banner and New American Banner are names under which the variety is best known in Canada.

Clawson, or White Clawson, is identical with Goldcoin, but as previously indicated, has an earlier history. Clawson or White Clawson was reported in 1919 from Connecticut, Colorado, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Washington, and West Virginia.

Fortyfold is the name under which Goldcoin was distributed by Peter Henderson & Co., (110), seedsmen, of New York City, as early as 1899. The variety is grown under this name chiefly in California, Oregon, Washington, Idaho, and Utah.

Klondike is the name under which the same wheat was distributed by J. M. Thorburn & Co. (191), New York City, in 1908. It is grown in New York under this name. No. 6 was applied to this wheat by Hickox-Rumsey Seed Co., Batavia, N. Y. It is claimed by Mr. Rumsey that the name No. 6 antedates Goldcoin. International No. 6, Rochester No. 6, and possibly Improved No. 6, are names under which the variety was distributed by the International Seed Co., of Rochester, N. Y. The distribution of the variety under these names seems to date from about 1908. The Junior No. 6 is said to be an improved strain of No. 6, but is identical with Goldcoin. It was named and distributed by the Hickox-Rumsey Seed Co., Batavia, N. Y. Goldcoin is mostly grown in New York under the names given in this paragraph.

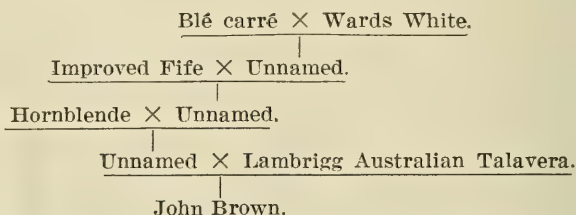
Prizetaker is the name used for the variety by the John A. Salzer Seed Co. (163), of La Crosse, Wis., as early as 1897, and possibly prior to that time. Prizetaker was reported from Illinois and Pennsylvania, but that grown in Illinois under this name is the variety known as Harvest Queen. Winter King is a name used for Goldcoin in Clearfield County, Pa.

JOHN BROWN.

Description.—Plant spring habit, early, tall; stem white, strong; spike awnless, fusiform to linear-oblong, middense, erect; glumes glabrous, brown, midlong, midwide; shoulders midwide, oblique to square; beaks narrow, acute, 1 mm. long; apical awns few, 3 to 15 mm. long; kernels white, mid-sized, soft, usually ovate; sometimes oval or elliptical; germ mid-sized; crease narrow to midwide, deep; cheeks rounded; brush mid-sized, midlong to long.

History.—The variety is of Australian origin, being one of the many crossbred wheats produced by William Farrer.

John Brown is the result of a rather complicated cross and has the following pedigree:



¹³ Reisner, John H. Wheat in New York. 1915. Unpublished thesis, Cornell University.

The cross was made in 1896 and named in 1901 (188, p. 282-283).

The first introduction of the variety into the United States is believed to have been in the fall of 1909, when F. D. Farrell, superintendent of the Nephi substation, Nephi, Utah, obtained a small quantity of the seed from the Department of Agriculture of New South Wales, Australia. Later introductions have been made by the United States Department of Agriculture (197, S. P. I. No. 36582) and also by the Wyoming Agricultural Experiment Station, which has distributed the variety in that State (151, p. 20).

Distribution.—Grown by the California and Wyoming stations and commercially in Wyoming.

ALLEN (RED ALLEN).

Description.—Plant spring habit, late, tall; stem white, midstrong; spike awnless, linear-fusiform, lax, inclined, glumes glabrous, brown, long, narrow; shoulders wanting to narrow, oblique; beaks narrow, acute, 1 mm. long; apical awns several, 5 to 20 mm. long; kernels white, midlong, semihard, ovate; germ usually small; crease wide, shallow; cheeks usually angular; brush small, midlong.

This variety is distinct because of its long lax spike. Spikes, glumes, and kernels are shown in Plate XXIV, A.

History.—The origin of Red Allen is undetermined. It has been grown in Washington for about 20 years.

Distribution.—Grown as Red Allen in Chelan, Douglas, Grant, and Okanogan Counties, Wash., and as Wolf Hybrid in Latah County, Idaho.

Synonym.—Wolf Hybrid. This variety has been commercially grown since about 1905. According to Hunter (124, p. 22) it was quite widely grown in Idaho in 1907, but since then it has largely disappeared from cultivation.

FEDERATION.

Description.—Plant spring habit, early, short; stem white, strong; spike awnless, oblong, dense, erect; glumes glabrous, brown, short, wide; shoulders wide, oblique to square; beaks narrow, acute, 0.5 mm. long; apical awns almost wanting; kernels white, usually short, soft, broadly ovate; germ midsized; crease usually narrow, shallow; cheeks rounded; brush midsized, midlong. Spikes, glumes, and kernels of this variety are shown in Plate XXV, A.

History.—According to Richardson (158, pp. 124-126)—

It was produced by the late Mr. Farrer, wheat experimentalist, of New South Wales (Australia), from a cross between Purplestraw and Yandilla. Yandilla is a cross between Improved Fife and Etewah, an Indian variety. The production of this wheat was probably the greatest of Mr. Farrer's many triumphs in wheat breeding, for none of his many successful crossbred wheats have enjoyed such a wide measure of popularity as Federation.

Federation was first introduced into the United States by the United States Department of Agriculture (197, S. P. I. No. 38347) in 1914 from seed furnished by E. A. Cook, of Perth, West Australia. The variety first showed promise in nursery experiments at the Sherman County branch station, Moro, Oreg., in 1916, and was increased and thoroughly tested (67, p. 10). The first distribution to farmers for commercial growing was in the spring of 1920.

Distribution.—Grown by several experiment stations in the western part of the United States and commercially to a small extent in Oregon in 1920.

FOISY.

Description.—Plant spring habit, late, tall; stem white, strong; spike awnless, linear-clavate, middense to lax, erect; glumes glabrous, brown, midlong, midwide; shoulders narrow, rounded to oblique; keel incurved above; beaks wide,

truncate, 1 mm. long; apical awns few, 3 to 15 mm. long; kernels white, short, soft, ovate; germ mid-sized; crease midwide, shallow to middeep; cheeks usually rounded; brush mid-sized, midlong.

Foisy wheat is easily distinguished by the tall plant and the long, rather lax, but clavate spike. Plate XXIV, *B*, shows spikes, glumes, and kernels of Foisy wheat.

History.—This variety originated on the farm of M. G. Foisy, near the site of West Woodburn, in northern Marion County, Oreg. About 1865, Mr. Foisy "noticed a head of red chaff wheat in his field of white chaff wheat, of unusual size, gathered it, and planted it in his garden until he had sufficient to seed a small field. Mr. Foisy, who was a Frenchman, was too modest to call it after his name, but insisted that it was Oregon Red Chaff, yet there is no one about him that knows it by any other name than Foisy" (100, p. 10).

Distribution.—Grown in 11 counties of western Oregon.

Synonym.—Oregon Golden Chaff, Oregon Red Chaff, and Red Chaff. These are all local names used for the variety in Oregon.

HARD FEDERATION.

Description.—Plant spring habit, early, short; stem white, strong; spike awnless, oblong, dense, erect; glumes glabrous, brown, short, wide; shoulders wide, square; beaks narrow, acute, 0.5 mm. long; apical awns wanting; kernels white, short, hard, ovate, with truncate tip; germ large; crease midwide, middeep, frequently pitted; cheeks angular to rounded; brush large, midlong.

Hard Federation differs from Federation in being slightly shorter and in having a hard kernel. Spikes, glumes, and kernels of Hard Federation are shown in Plate XXV, *B*.

History.—Hard Federation was originated by selection from the Federation in Australia. The following history was recorded (30, p. 664) in 1914:

In consequence of the variations of the ordinary type exhibited by the strain of Federation wheat now being grown at Cowra Experiment Farm, it has been deemed advisable to apply a distinct name to it, and "Hard Federation" has been selected as the most appropriate. The departure from type was first noticed by J. T. Pridham, plant breeder, in 1907 or 1908, one of the plants selected from the stud plats being observed to thrash grain of remarkably hard and flinty appearance. The plant has the distinctive brown head and general appearance of Federation in the field, but the grain was of a class that has never been seen in the variety before. The seed was propagated, and in 1910 the occurrence of white heads was noticed, and from then until 1912 distinctly white heads were common among the brown, but in 1913 there were no white-eared plants, and it is hoped that the seed will now be true to type.

Hard Federation was first introduced into the United States in August, 1915, by the United States Department of Agriculture (197, S. P. I. No. 41079). The seed was presented to the United States Department of Agriculture by George Valder, undersecretary and director of the Department of Agriculture, Sydney, New South Wales. It was first grown at the Sherman County Branch Station, Moro, Oreg., in 1916. Experiments conducted by the Department in Oregon and California from 1917 to 1919, reported by Clark, Stephens, and Florell (67, p. 12-17), have shown it to be a high-yielding, dry-land wheat, and it has since been increased and distributed.

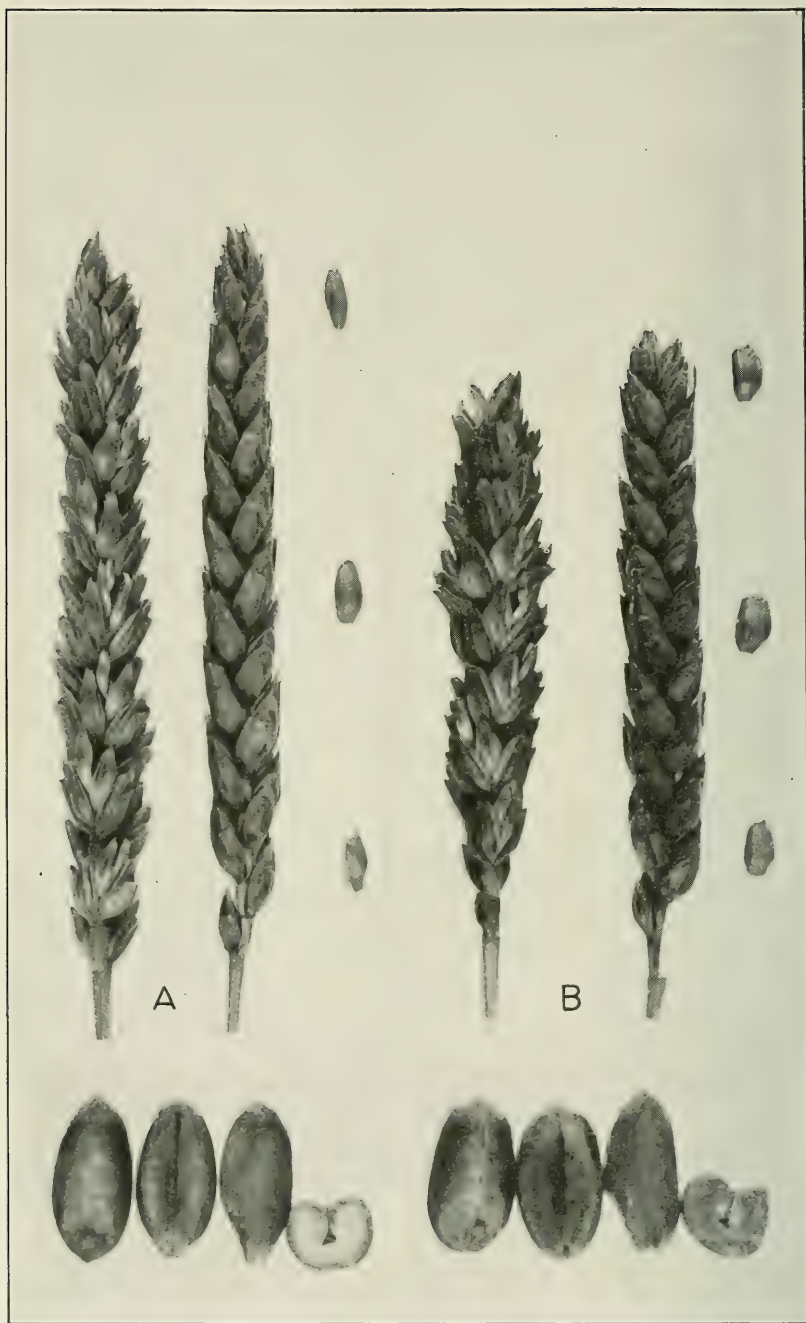
Distribution.—Grown at several experiment stations in the western part of the United States and commercially to a slight extent in California and Oregon in 1920.



ALLEN (A).

FOISY (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



FEDERATION (A).

HARD FEDERATION (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



RED WAVE (A).

ODESSA (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



RUPERT (A).

RURAL NEW YORKER NO. 6 (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

GOLD DROP.

Description.—Plant winter habit, early, midtall; stem white, weak to midstrong; spike awnless, short, fusiform, middense, erect to inclined; glumes glabrous, brown, short to midlong, midwide to wide; shoulders wide, oblique to square; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 10 mm. long; kernels red, short to midlong, soft, ovate; germ midsized; crease midwide, middeep; cheeks rounded; brush small, midlong.

Gold Drop is distinguished from other wheats of this group by its earliness and by the short, fusiform spike.

History.—This doubtless is the old English variety usually referred to as Golden Drop. Koernicke and Werner (133, p. 295) state that this variety was bred in 1834 by a Mr. Gorrie, at Annat Garden in Great Britain. It has been grown in the United States for many years, being mentioned by Rawson Harmon, of Wheatland, Monroe County, N. Y., in 1843 (103, p. 228). The samples furnishing the plants here described were obtained from Izard County, Ark., where farmers state that it has been grown for at least 25 years.

An improved strain of Golden Drop, called Hallet's Pedigree Golden Drop, was used by Cyrus G. Pringle as one of the parents of Defiance.

Distribution.—Grown as Gold Drop in Arkansas, Missouri, and Pennsylvania, and as Littleton in Humphreys County, Tenn. A bearded spring wheat called Gold Drop was reported in Iowa.

Synonyms.—Golden Drop, Littleton.

HOMER.

Description.—Plant winter habit, midseason, midtall to tall; stem white, midstrong; spike awnless, oblong-fusiform; middense, erect to inclined; glumes glabrous, brown, midlong, midwide; shoulders midwide, oblique to elevated; beaks wide, obtuse, 0.5 to 1.0 mm. long; apical awns few, 2 to 10 mm. long; kernels red, midlong, soft, ovate; germs midsized to large; crease wide, middeep; cheeks angular; brush small to midsized, midlong, sometimes collared.

Homer differs from Red Wave in having an inclined instead of a nodding spike.

History.—The origin of this variety is undetermined. The plants described were grown from seed obtained from Chatham County, N. C., in 1919, where it had been grown for the past 10 years.

Distribution.—Grown in Chatham County, N. C.

RED WAVE.

Description.—Plant winter habit, midseason to late; midtall to tall; stem white, midstrong; spike broadly fusiform, middense, nodding; glumes glabrous, brown, midlong, wide; shoulders wide, rounded to oblique, sometimes nearly square; beaks wide, obtuse, 1 mm. long; apical awns several, 5 to 15 mm. long; kernels red, midlong, soft, ovate; germ midsized; crease midwide to wide, middeep, sometimes pitted; cheeks usually angular; brush midsized, midlong.

Red Wave is distinguished by the broadly fusiform, nodding spike. It is inferior to many other soft red winter wheats for milling and bread making. Spikes, glumes, and kernels of this variety are shown in Plate XXVI, A.

History.—Originated by A. N. Jones, Le Roy, Genesee County, N. Y., in 1906, as the result of a cross between Early Red Clawson and an unnamed crossbred wheat of Russian parentage (110, 1908).

Distribution.—Grown in Arkansas, Connecticut, Delaware, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Missouri, New Jersey,

New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin. This distribution is shown in Figure 39.

Synonyms.—Advance, Indiana Red Wave, Jones Red Wave, Old Dutch, Red Chaff, Red Ivory, Red Wafer, Ruble, Rust Proof, Waif, Waverly, and Worlds Fair.

Old Dutch, Red Chaff, Red Ivory, Red Wafer, Waif, Waverly, and Worlds Fair are local names used by growers, chiefly in Indiana. Advance is a name under which this wheat was distributed by the John A. Salzer Seed Co., of La Crosse, Wis. Indiana Red Wave is the name used for the variety by growers in States adjoining Indiana who obtained their seed from that State, as Red Wave is a rather widely grown variety in Indiana.

Jones Red Wave is a name used because the variety was originated by A. N. Jones, as stated above. Ruble is a variety similar to Red Wave, except for having a denser and less nodding spike. It was obtained from H. W. Anderson, Washington College, Tenn., who states that it has been grown in Washington County, Tenn., for the past 20 years. Rust Proof is the name under which a sample of Red Wave was obtained from Osceola County, Mich.

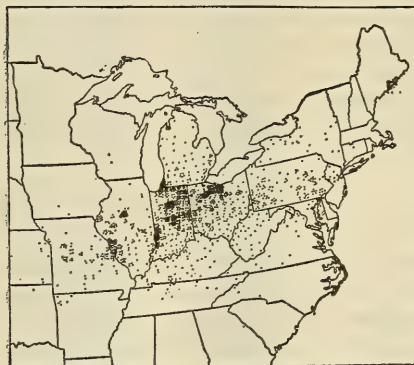


FIG. 39.—Outline map of a portion of the northeastern United States, showing the distribution of Red Wave wheat in 1919. Estimated area, 1,132,400 acres.

named it 'Russian Club.' Several hundred acres now are grown about Forsyth, Mont.

Distribution.—Grown by the Montana Agricultural Experiment Station as Fleming and commercially in Rosebud County, Mont., as Russian Club.

Synonyms.—Russian Club, Winter Club. These names are both used by growers in Rosebud County.

FLEMING.

Description.—This variety differs from Red Wave only in being slightly later and in having a somewhat narrower and less nodding spike.

History.—Fleming was imported from Russia. According to officials of the Montana Agricultural Experiment Station, in correspondence with the Office of Cereal Investigations, "Mr. E. E. Fleming obtained it from a friend from Russia, since dead, and

PETERSON (LARS PETERSON).

Description.—Plant winter habit, midseason, tall; stem white, midstrong; spike awnless, broadly fusiform, long, middense, nodding; glumes glabrous, brown, midlong, midwide to wide; shoulders midwide, oblique to rounded; beaks wide, obtuse, 1 mm. long; apical awns few, 2 to 5 mm. long; kernels red, midlong, soft, broadly ovate; germ midsized; crease wide, middeep to deep, sometimes pitted; cheeks usually angular; brush midsized, midlong.

Peterson differs from Red Wave in being slightly taller and in having a longer spike and narrower glumes and shoulders.

History.—The history of Peterson wheat is undetermined. The following statements relate to its culture in Arizona:

A wheat known locally as Lars Peterson grows fairly well in high altitudes under dry-farming conditions. County agents think it fairly promising for dry-land cultivation.¹⁴

Peterson wheat has been planted in this section of the country for the past 25 years, but of late Bluestem spring wheat has been planted more extensively.¹⁵

Distribution.—Grown in Navajo County, Ariz.

ODESSA.

Description.—Plant winter habit, late, midtall to tall; stem usually white, midstrong; spike awnless, fusiform, middense to lax, inclined; glumes glabrous, brown, long, midwide, shoulders midwide, usually oblique to square, sometimes elevated; beaks usually wide, obtuse, 1 mm. long; apical awns several, those below apex strongly incurved or recurved, 5 to 20 mm. long; kernels red, midlong, soft, ovate to elliptical; germ small; crease midwide, middeep; cheeks usually rounded; brush small, midlong to long.

Odessa is very winter hardy. It is distinguished from other varieties in this group by its late maturity and its slender fusiform spike. Different strains of Odessa vary widely, due in part to natural field hybridization. Several white-kerneled strains have been selected from these natural hybrids, one of which appears to be immune to bunt. Because of its winter resistance, it often is used as one parent for crosses in breeding for greater winter resistance. Minhardi and Minturki, winter-hardy varieties developed at the Minnesota Agricultural Experiment Station, are the result of a cross between Odessa and Turkey. Spikes, glumes, and kernels of Odessa wheat are shown in Plate XXVI, B.

History.—According to Carleton (58, p. 53) Odessa is of Russian origin. Several introductions have been made. The variety was grown in Minnesota as early as 1865:

The Odessa wheat is one of the importations of the United States Department of Agriculture that is coming into notice and favor. It was started, says the Lake City (Minn.) Leader, by Porter Martin, of Dakota County, four years ago, from a small package of seed sent him by Hon. Ignatius Donnelly and has been grown exclusively on his farm till this year, for the purpose of giving it a reliable test (5, p. 238).

The variety was included among a number of wheats obtained by the Minnesota Agricultural Experiment Station in 1893 and 1894 from American consuls and from seed dealers in Russia (109, p. 40). It is evident, however, that the variety was quite widely grown in the United States before that time. A variety known as Odessa was grown by the Wisconsin College of Agriculture in 1875 (12). A sample of Odessa wheat obtained from the Black Sea region was grown by the Colorado Agricultural Experiment Station in 1879 (46, p. 40). It also was reported to have been grown in Utah for 40 years, having been taken there from the Eastern States by Mormon settlers, and in California in the seventies and eighties, because of its resistance to rust in the coastal areas.

Distribution.—Grown in California, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Missouri, Nebraska, Tennessee, Utah, Wisconsin, and Wyoming. A map showing the distribution of Odessa wheat is presented as Figure 40.

Synonym.—Grass. This was reported as a synonym for Odessa by Tracy in 1880 (195, p. 396). A sample of Grass wheat nearly identical with Odessa was obtained from W. E. Bass, of Stevensville, Mont., in 1918, who states that

¹⁴ Letter of Prof. W. E. Bryan, University of Arizona, Tucson, Ariz., Mar. 31, 1917.

¹⁵ Varietal Survey. Report of James L. Hall, Pinedale, Navajo County, Ariz., 1919.

it has been grown for five to eight years to a very limited extent, both as a winter and a spring wheat in Ravalli County, Mont. Carleton stated that Odessa could be grown as either a winter or a spring wheat. Most samples grown by the writers showed the winter habit, but as some strains are heterozygous for winter and spring habit a portion of the crop from the bulk variety would produce seed from spring sowing.

RUDDY.

Description.—Plant winter habit, late, tall; stem glaucous, white, strong; spike awnless, oblong, middense, erect to inclined; glumes glabrous, light brown, short, wide; shoulders wide, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns few, 2 to 8 mm. long; kernels red, midlong, soft, oval; germ midsized; crease midwide, middeep; cheeks angular; brush midsized, long.

This is a high-yielding variety, but its milling quality is poor.

History.—Ruddy was originated by hybridization at the Washington Agricultural Experiment Station, Pullman, Wash. It has Jones Fife, Little Club, and



FIG. 40.—Outline map of the northwestern United States, showing the distribution of Odessa wheat in 1919. Estimated area, 54,200 acres.

Turkey in its parentage and is a selection from the same cross from which Triplet was obtained. Ruddy was grown first as a pure line in 1910 and was named and distributed to a few farmers in the fall of 1919.

Distribution.—Grown experimentally in Washington.

RUPERT (RUPERT'S GIANT).

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awnless, linear-oblong to subclavate, middense, nodding; glumes glabrous, brown, midlong, wide; shoulders wanting to narrow to midwide, oblique; beaks wide, obtuse, 1.0 long; apical awns several, 2 to 20 mm. long; kernels red, midlong, soft, ovate to elliptical; germ small to midsized; crease wide, middeep to deep; cheeks usually rounded; brush midsized, midlong.

Rupert differs from Red Wave in having an oblong spike, which sometimes is subclavate. Spikes, glumes, and kernels of this wheat are shown in Plate XXVII, A.

History.—The origin of this variety is not definitely known. Apparently it was first grown under the name Woods, concerning which R. Crouch, of Morristown, Tenn., wrote the Office of Cereal Investigations, as follows:

Mr. William Woods, of Talbott, Tenn., many years ago noticed an extra head of wheat in his field, and from this head of wheat Woods wheat is largely raised in this (Hamblen) and adjoining counties.

Another early name for the variety is Hartzel. John D. Daley, of Clinton, Ohio, in correspondence with the Office of Cereal Investigations, in 1919, states that this wheat "was selected out of some wheat grown by Joe Hartzel, of Barberton, Ohio, about 18 years ago."

A wheat under the name Rupert's Giant probably was first advertised by J. M. Thorburn & Co., seedsmen, of New York City (191), but this was described as "a red, bearded wheat, long stem, strong growing, resists the Hessian fly best." Rupert's Giant, grown by the writers from samples obtained from the Cornell University (N. Y.) Agricultural Experiment Station in 1913 and 1917, is awnless and is as described above.

Distribution.—Grown in Dickinson County, Kans., and under the synonyms in Kentucky, Michigan, Ohio, and Tennessee. The variety was grown in New York several years ago, but has now probably gone out of cultivation in that State.

Synonyms.—Gold Medal, Hartzel, Haskell, Red Hassel, Red Haskell, Ruck, and Woods.

Gold Medal is the name used for the variety grown in the vicinity of Morley, Mecosta County, Mich. Hartzel, Haskell, Red Hassel, and Red Haskell are names used by growers in Ohio. E. F. Cranz, of Ira, Ohio, wrote the Office of Cereal Investigations in 1919 concerning Red Haskell as follows:

I think it is safe to say that one-half the acreage in Summit County this year is of that variety. It has been grown here about 8 or 10 years and became very popular soon after it was introduced.

Ruck is the name under which a sample of this variety was obtained at Dennis, Lawrence County, Ky. Woods, as indicated above, is the name under which the variety is grown in Blount County, Tenn.

RURAL NEW YORKER NO. 6.

Description.—Plant winter habit, early, short; stem white, stout, midstrong; spike awnless, clavate, dense, erect to inclined; glumes glabrous, brown, midlong, wide; shoulders midwide to wide, oblique to square; beaks wide, obtuse, 1 mm. long; apical awns few, 5 to 20 mm. long; kernels red, small to midlong, soft, ovate, and broad across basal end; germ mid-sized; crease midwide, mid-deep; cheeks rounded; brush mid-sized, midlong.

This variety is distinguished by its dense, clavate spike. Spikes, glumes, and kernels of this variety are shown in Plate XXVII, B.

History.—This variety is reported to have been originated by crossing wheat and rye. The cross was made by Elbert S. Carman, editor of the Rural New Yorker, in the season of 1883 (23). The Martin variety, known also as Armstrong and Landreth, was the mother parent of the cross. Seed of the variety was first offered for sale by Peter Henderson & Co. (110), seedsmen, of New York City, in 1894. Leighty (139, p. 426), in reviewing Mr. Carman's wheat-rye hybrids, gives the following conclusions regarding Rural New Yorker No. 6:

From this description, and from a statement made elsewhere concerning its origin, it seems that No. 6 is actually descended from the true wheat-rye hybrid obtained in 1883. It is noteworthy for the fact, since it is the only variety introduced by Mr. Carman, whose record, so far as determined by the writer, clearly indicated such origin.

Distribution.—Possibly grown as No. 6 in Michigan, New York, and Ohio. Its distribution has become so confused with Goldcoin, which also is called No. 6, that no definite distribution can be given.

Synonyms.—Burtaker, No. 6, Red Hussar, and Twentieth Century. Burtaker is the name under which the variety has been grown in Cheboygan County, Mich., for the past 8 years. No. 6 is an abbreviation of the full name, and

is the name used by most growers in New York. Red Hussar is a name under which this variety was obtained from the Cornell University Agricultural Experiment Station. The true Red Hussar, however, is an awned variety. Twentieth Century is the name used for the variety in Erie County, Ohio, where it has been grown for 15 years or more.

SQUAREHEADS MASTER.

Description.—Plant winter habit, late, midtall; stem white, strong, stout; spike awnless, clavate, dense, erect; glumes glabrous, brown, midlong, wide; shoulders wanting to narrow, oblique; beaks wide, obtuse, incurved, 1 mm. long; apical awns few, 1 to 10 mm. long; kernels red, midlong, soft, broadly ovate; germ small to midsized, abrupt; crease midwide, middeep; cheeks rounded; brush large, midlong. Differs from Red Russian only in having brown glumes.

History.—The variety described above is found rather commonly as a mixture in fields of the Red Russian variety in Idaho and Washington. Squareheads Master is an English variety, and the history of its introduction to the Pacific Northwest is not known. A sample introduced from England in 1911 by the United States Department of Agriculture is very similar to several selections the writers have made of the mixtures in Red Russian fields in Washington and also to a selection from a field of Red Russian made by Glen Roundtree, Boistfort, Lewis County, Wash., who increased it and now has a field of the variety. In England, Squareheads Master is reported to have been selected by Mr. Teverson from Scholey's Squarehead, and is probably the result of a natural cross between Scholey's and the Golden Drop (85; 155, p. 33).

Distribution.—Grown as a mixture in fields of other varieties in California, Idaho, and Washington, and in pure culture to a very limited extent in Lewis County, Wash.

Synonyms.—Australian Club, Brown Squarehead, Redchaff Red Russian. Australian Club is the name which was first used for the Brown Squarehead wheat by Mr. Roundtree. Brown Squarehead and Redchaff Red Russian have been used as names to describe the wheat where it occurs as mixtures, because it differs from the Squarehead and Red Russian varieties principally in glume color.

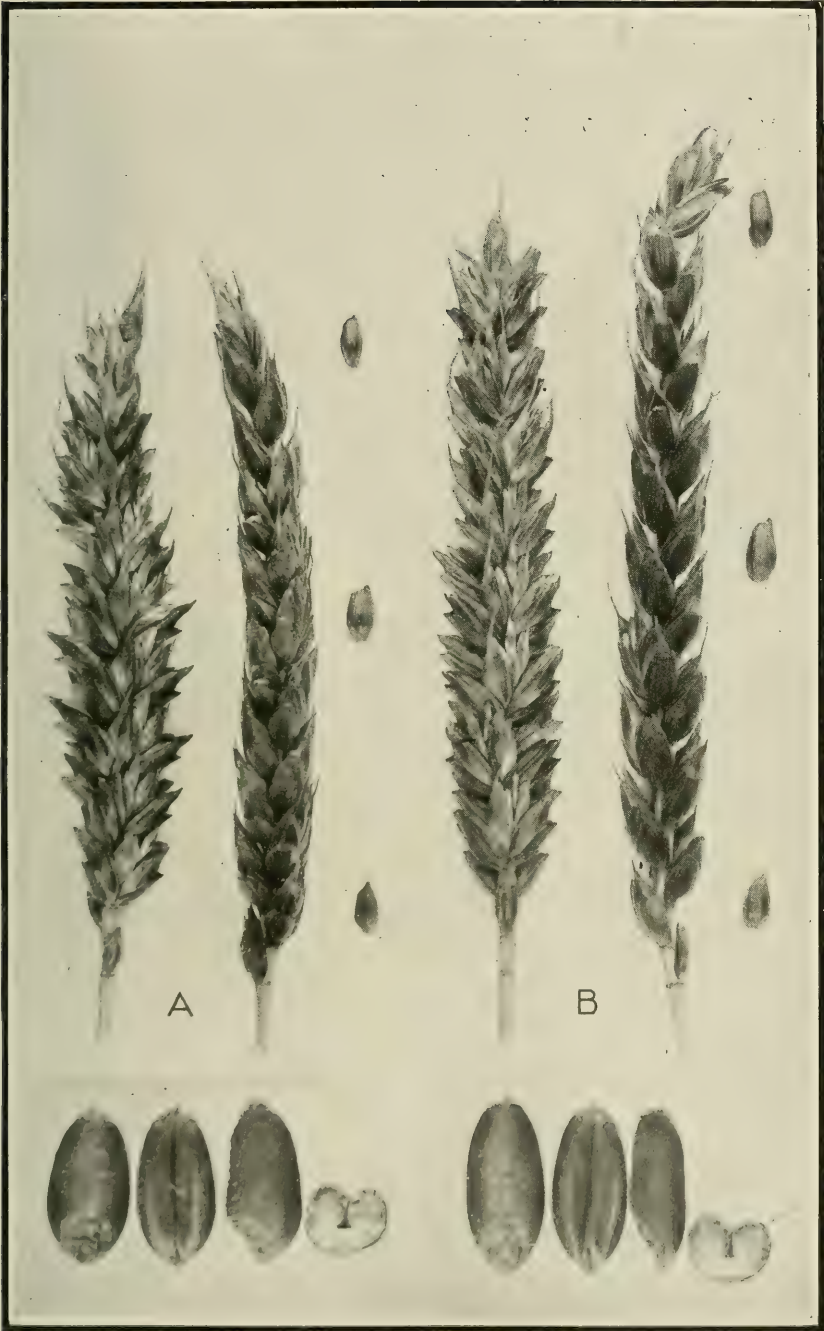
CURRELL (CURRELL'S PROLIFIC).

Description.—Plant winter habit, early, midtall; stem usually purple, midstrong; spike awnless, fusiform, middense, inclined; glumes glabrous, brown, midlong, narrow to midwide, shoulders midwide, oblique to square; beaks usually wide, sometimes nearly wanting, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels dull red, short to midlong, soft, ovate; germ midsized; crease narrow to midwide, shallow to middeep, distinctly triangular; cheeks usually rounded; brush small, midlong.

Currell is distinguished from other varieties in this group of purple-strawed wheats by its slender spike. Spikes, glumes, and kernels of this variety are shown in Plate XXVIII, A.

History.—The history of Currell (Currell's Prolific) has been recorded by Carleton (61, p. 202) as follows:

Currell Prolific wheat was selected by Mr. W. E. Currell, of Virginia, from a field of Fultz in 1881. The original seed was from three spikes. It was first sold for seed in 1884.



CURRELL (A).

POOLE (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



CHINA (A).

RED MAY (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

Distribution.—Grown in Alabama, Arkansas, Delaware, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Missouri, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. The distribution is shown in Figure 41.

Synonyms.—Gill, Golden Chaff, Pearl Prolific, Perfection, Prettybone, Prolific, Red Odessa, Red Prolific, and Tennessee Prolific.

Gill is a name used for Currell by growers in Kentucky. The name is also used for the Poole variety in the same State. Golden Chaff is practically the same if not entirely identical with Currell. The origin of this variety is not known. It has been grown by the Alabama Agricultural Experiment Station since 1902 (§3, p. 106–111). T. W. Wood & Sons, seedsmen, of Richmond, Va., have advertised and distributed the variety in the Southeastern States since about 1905. It has been reported from nearly all the States in which Currell is grown.

Pearl Prolific is probably a mispronunciation of the name Currell Prolific. A sample of this variety obtained from the Cornell University station in 1912 proved to be identical with Currell. Pearl Prolific is grown in Alabama, Indiana, Kansas, Kentucky, Maryland, Missouri, Ohio, Tennessee, and Virginia. Perfection is apparently identical with Currell. It was grown by the Ohio Agricultural Experiment Station as early as 1895 (204, p. 39). Perfection is grown in Indiana, Missouri, Ohio, Pennsylvania, and Tennessee. Prettybone is the name of a wheat almost identical with Currell which was obtained in 1919 from Madison County, N. C., where it had been grown for at least four years.

Prolific is a shortening of the name of the variety as used by growers. Red Odessa is the name under which a sample of Currell was obtained from Smiths Grove, Ky., in 1919. Red Prolific is a name applied to Currell because of the color of the glumes. Tennessee Prolific is a name used for the variety in Alabama.

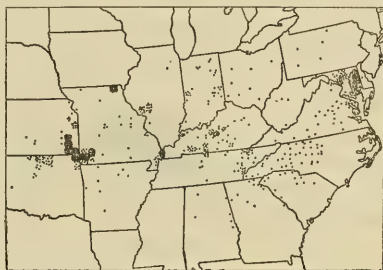


FIG. 41.—Outline map of the east-central United States, showing the distribution of Currell wheat in 1919. Estimated area, 645,000 acres.

WINTER CHIEF.

Description.—Plant winter habit, midseason, short; stem faintly purple, strong; spike awnless, broadly oblong, middense, erect to nodding; glumes glabrous, brown, long, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns several, 3 to 20 mm. long; kernels red, midlong, soft, ovate to oval, frequently elliptical, flattened; germ small; crease midwide, middeep to deep; cheeks usually rounded; brush small to mid-sized, midlong.

Winter Chief differs from Poole principally in being shorter and having more erect spikes.

History.—The origin of Winter Chief is undetermined. A sample was obtained from the Indiana Agricultural Experiment Station in 1913, which in turn had received it from Everitt's O. K. Seed Store, Indianapolis, Ind.

Distribution.—Winter Chief is not known to be commercially grown.

POOLE.

Description.—Plant winter habit, midseason, midtall; stem purple, midstrong; spike awnless, usually fusiform, sometimes nearly oblong or linear-oblong, wide, middense to lax, usually nodding; glumes glabrous, brown, midlong, wide; shoulders wide, oblique to square; beaks wide, obtuse, 0.5 mm. long; apical awns several, 3 to 20 mm. long; kernels red, midlong, soft, ovate to oval, frequently elliptical, flattened; germ small to mid-sized; crease midwide, middeep to deep; cheeks usually rounded; brush small to mid-sized, midlong.

This variety is distinguished by the wide, nodding spikes. The kernels are rather narrow, flattened, and rounded in outline. Spikes, glumes, and kernels of Poole wheat are shown in Plate XXVIII, B, and a single spike in Plate V, Figure 4.

History.—The origin of the Poole variety is undetermined, but it has been an important variety in Ohio and Indiana for about 35 years. It was grown

by the Ohio Agricultural Experiment Station as early as 1884 (19, p. 15).

Distribution.—Grown in Alabama, Delaware, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Missouri, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and West Virginia, and under names of synonyms in Arkansas and Oklahoma in addition. This distribution is shown in Figure 42.

Synonyms.—Beechwood or Beechwood Hybrid, Bluestem, California Red, Gill, Harvest King, Hedge Prolific, Hundred Mark, Hydro Prolific, Mortgage Lifter, Kentucky Bluestem, Nissley or Nissley's Hybrid, Ocean Wave, Oregon Red Chaff, Red or California, Red Amber, Red Chaff, Red Fultz, Red King, Red

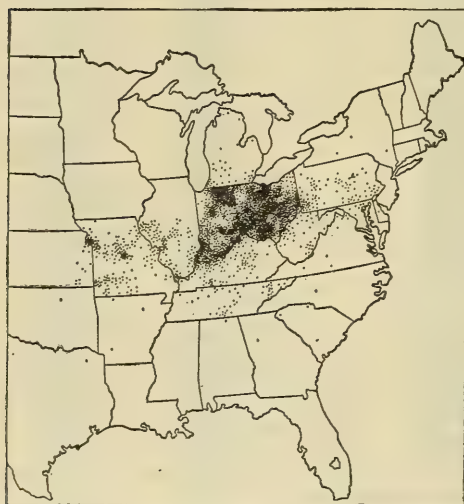


FIG. 42.—Outline map of the eastern United States, showing the distribution of Poole wheat in 1919. Estimated area, 2,453,400 acres.

Russell, Royal Red Clawson, Sweet Water Valley, Wagner, and Winter King.

Beechwood (originally Beechwood Hybrid) was distributed by J. W. Stillwell, Troy, Ohio, about 1898. In a letter under date of July 15, 1898, to the Office of Cereal Investigations he has given the history as follows:

Mixed one-half bushel Rudy, one-half bushel Red Fultz (not Mediterranean), one-half bushel Red Velvet Chaff together. The third year from mixture I named Beechwood Hybrid. Mixed because Rudy is soft straw and large grain, Velvet strong straw and small grain, Fultz was put in to get rid of beards.

A mixture of Poole and Red May is now most generally grown as Beechwood. It has largely disappeared from commercial culture.

Bluestem and Kentucky Bluestem are names used by growers for the Poole variety because of its purple straw. Kentucky Bluestem was reported from Arkansas, Georgia, Michigan, Missouri, South Carolina, and West Virginia.

California Red is a name occasionally used for the variety under the supposition that the seed came originally from California. A sample of Poole

called Red or California was obtained in 1919 from Warren County, Tenn., where it had been grown for at least 30 years. Gill is a name used for Poole by many growers in Kentucky.

Harvest King was distributed by J. A. Everitt & Co., (89, p. 4-7) seedsmen, of Indianapolis, Ind., from 1894 to about 1900. There is no information regarding the origin of the variety, and it probably is only a lot of seed of the Poole variety renamed by the Everitt Seed Co., as such renaming was a common practice of that firm. As the wheat was widely advertised under this name, it is now grown nearly as widely under the name Harvest King as under the name Poole itself. It was reported grown in Arkansas, Delaware, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Missouri, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Virginia, and West Virginia.

Hedge Prolific, a wheat apparently identical with Poole, but of undetermined origin, was grown by the Indiana Agricultural Experiment Station as early as 1884 (135, p. 4). It is not known to be commercially grown now.

Hundred Mark is the name used for Poole in Hocking County, Ohio, for 22 years or more. The same name is sometimes used for the Prosperity variety in Indiana. Hydro Prolific is the name under which a sample of Poole was obtained from Rosedale, Ind. Mortgage Lifter is a local name applied to Poole wheat in Pennsylvania. Nissley (originally Nissley's Hybrid) is an old name for a wheat apparently identical with Poole. It has been grown at the Arlington Experimental Farm, Va., since 1913. As far as known it is not now commercially grown.

Oregon Red Chaff is a name used for Poole in Illinois. Red Amber is a name used for Poole in Pennsylvania. Red Chaff is a common synonym of Poole because of its brown glumes. Red Fultz is a name often but wrongly applied to Poole wheat in Indiana, Ohio, and Kansas. Red King and Winter King are confusions of the name Harvest King, a synonym of Poole. A sample of Winter King was obtained from Mulberry, Ind., in 1919.

Red Russell is a synonym for Poole in Michigan. Royal Red Clawson is apparently identical with Poole, but of undetermined origin. It is known to have been grown commercially in New York several years ago, but probably has now disappeared from cultivation. Sweet Water Valley is the name under which a sample of Poole was obtained from Greene County, Tenn. Wagner is a name used for Poole in Indiana.

PORTAGE.

Description.—This variety is similar to Poole except in having a stiffer straw and a higher yield and quality.

History.—Portage is a pure-line selection of Poole developed at the Ohio Agricultural Experiment Station. It is recommended by the Ohio station as a high-yielding wheat superior to Poole for milling and bread making (205, p. 478-481).

Distribution.—Grown in New York, Ohio, and Pennsylvania.

RUSSIAN RED.

Description.—Russian Red differs slightly from Poole in having more persistent glumes which have more triangular shoulders and longer beaks.

History.—This variety usually is grown under the name "Red Russian," but as other varieties are known by this name it is here designated as Russian Red. The following history of Red Russian wheat was reported by E. H. Collins, who was offering the seed for sale in 1898:

In answers to questions, allow me to say that the Red Russian wheat I advertise in the Farmer was selected by an agent sent by the American Seed Co.,

of Rochester, N. Y., to Russia to secure their best wheat. It was introduced in this section by a prominent mill in Indianapolis at \$1.50 a bushel. They paid 1 cent extra for a few years to encourage its more general introduction. It has of late years sold at the seed stores at a 2-cent premium and does this year. It is hardy, smooth, medium hard, and very productive. The only fault I found in growing it 12 years is that it shatters when cut dead ripe, so that I often grow half of my crop Fultz, which can wait. Lately, however, I grow all Russian (73, p. 7).

The Red Russian variety was grown by the Ohio Agricultural Experiment Station as early as 1888 (113, p. 29). It was distributed widely by Peter Henderson

& Co. (110), seedsmen, of New York City, and J. A. Everitt & Co. (89), seedsmen, of Indianapolis, Ind., in the early nineties.

Distribution.—Grown in Illinois, Indiana, Kentucky, Michigan, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Texas, Virginia, and West Virginia. (Fig. 43.)

Synonym.—Red Russian.

CHINA.

Description.—Plant winter habit, late, tall; straw purple, weak to midstrong, spike awnless, fusiform, middense to lax, inclined; glumes glabrous, brown,

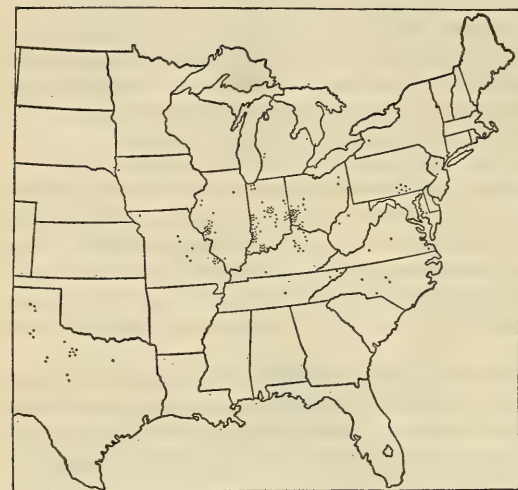


FIG. 43.—Outline map of the eastern United States, showing the distribution of Russian Red wheat in 1919. Estimated area, 172,000 acres.

midlong, midwide; shoulders narrow to midwide, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 3 to 12 mm. long; kernels red, short to midlong, soft, ovate to elliptical, tip end usually flattened, ventral side slightly dished; germ small; crease narrow to midwide, shallow to mid-deep; cheeks rounded; brush small, midlong, collared.

China differs principally from Currell in being taller and later and in having a different shaped kernel, as shown in the descriptions. Spikes, glumes, and kernels of China wheat are shown in Plate XXIX, A.

History.—In 1851 the Rural New Yorker gave the following account of the origin of "China" wheat, which appeared for the first time in the Niagara Democrat:

The kernels from which they (specimens) grew were originally brought from China some six years ago (1845). The seed was handed to Mr. Caverns by O. Turner, the popular local historian, who obtained them from the then lately returned Minister to China, Hon. Caleb Cushing. From a small quantity received by Mr. Caverns for experiment, an amount sufficient to give it extensive and permanent culture has been received.

Several other histories of the origin of "China" wheat are recorded in literature, but the above is thought to be the correct history of the variety here described.

Distribution.—Grown in Illinois, Indiana, Kentucky, Maryland, New Jersey, Pennsylvania, Virginia, and West Virginia. The distribution is shown in Figure 44.

Synonyms.—Bluestem, Lebanon Valley, Mortgage Lifter, and Pennsylvania Bluestem. Bluestem and Pennsylvania Bluestem are names widely used for China in the States where it is grown. A. H. Hoffman, seedsman, of Landisville, Pa., has distributed the variety in that State under the name Pennsylvania Bluestem.

Lebanon Valley is the name under which a sample of China was obtained from R. Chester Ross, of Honey Brook, Pa., who stated that the variety "Originated in Lebanon Valley, Pa."

Mortgage Lifter is the name under which a sample of China was obtained from the Cornell University station in 1912.

WHEELDLING.

Description.—Plant winter habit, late, midtall to tall; stem purple, strong; spike awnless, oblong-fusiform, middense, erect; glumes glabrous, light brown, midlong to long, midwide; shoulders wanting to narrow, oblique; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns few, 3 to 15 mm. long; kernels red, midlong, soft, ovate; germ mid-sized; crease midwide, middeep; cheeks angular; brush small, midlong.

Wheedling differs from China in being shorter and in having a more erect spike and narrower shoulders.

History.—"This variety was originated about 18 years ago (1890) by Louis Wheedling, of Indiana. Mr. Wheedling, while walking in his wheat field, noticed some heads slightly different from the surrounding ones. These he selected, and from them came the variety that bears his name" (122, p. 90).

Distribution.—Grown in Cass, Clinton, Elkhart, Marshall, and St. Joseph Counties, Ind.

RED MAY.

Description.—Plant winter habit, early, midtall to tall; stem purple, midstrong; spike awnless, usually oblong, middense, erect to inclined; glumes glabrous, brown, short to midlong, wide; shoulders wide, usually square; beaks narrow, triangular, 0.5 mm. long; apical awns few, 3 to 12 mm. long; kernels red, usually short, soft, ovate; germ mid-sized; crease midwide to wide, middeep to deep; cheeks usually angular; brush usually small, midlong.

Red May differs from Poole and China in being earlier and in having a broader and more oblong spike and wider glumes with squarer shoulders. The glumes and shoulders of Red May also are wider than those of Wheedling. Spikes, glumes, and kernels of Red May wheat are shown in Plate XXIX, B.

History.—The Red May is believed to be identical with or descended from the Red or Yellow Lammas. Several writers have suggested the identity. Tracy (195, p. 396) mentions Yellow Lammas as being a synonym of Red May. The Lammas was mentioned by Koernicke and Werner (133, p. 253 and 290) as being a very old English wheat grown previous even to 1699. Both the Red and Yellow Lammas were grown in Virginia many years before the Revolutionary War. A White May wheat of a later period, according to Cabell (56,

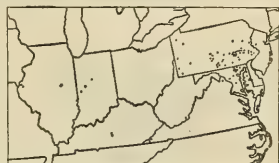


FIG. 44.—Outline map of a portion of the eastern United States, showing the distribution of China wheat in 1919. Estimated area, 63,900 acres.

p. 14), was grown in Virginia as early as 1764. A more recent history of Red May indicates that it was originated by General Harmon from the Virginia May (a white-kerneled wheat) about 1830 (103, p. 226). This wheat has been grown quite widely under the name Red May since 1845.

Distribution.—Grown in Alabama, Arkansas, Georgia, Illinois, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Nebraska, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia, and under the synonyms in Connecticut, Indiana, Michigan, Minnesota, Ohio, Pennsylvania, West Virginia, and Wisconsin (Fig. 45).

Synonyms.—Beechwood (in part), Canadian Hybrid, Early Harvest, Early May, Early Ripe, Enterprise, Jones Longberry, May, Michigan Amber, Michigan Wonder, Orange, Pride of Indiana, Red Amber, Red Cross, Red Republic, and Republican Red.

Beechwood usually is a mixed wheat containing some Red May. For a history of the wheat, see Poole. Canadian Hybrid is the name under which a

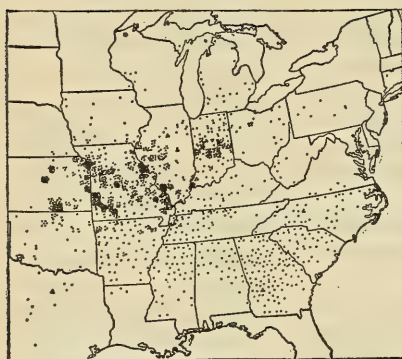


FIG. 45.—Outline map of the eastern United States, showing the distribution of Red May wheat in 1919. Estimated area, 1,165,900 acres.

sample of Red May was obtained from Illinois in 1919. The name Canadian Hybrid usually is used as a synonym of Jones Fife.

Early Harvest differs from Red May only in having a shorter and more oblong spike. Its history is not known, but the name apparently came into use by farmers of Indiana and Illinois in the late eighties. It was reported as grown in 1919 in Indiana, Kansas, Kentucky, Michigan, Missouri, and Ohio.

Early May was commonly used as a synonym for both Red May and White May from 1843 to 1857. In 1854 a White May variety in addition to the one already discussed is claimed to have been originated by Charles H. Boughton,

Center Crossroads, Essex County, Va. This was also known as Boughton and Tappahannock. The name Early May is now probably used partly for Red May, but principally as a synonym for the Little May or Flint. It was reported in 1919 from Alabama, Arkansas, and South Carolina.

Early Ripe was recorded as having been introduced into Darke County, Ohio, in 1840. During the next 18 years it became distributed over the State as Whig, Kentucky Red, and Carolina (131, p. 142). It apparently has continued in cultivation. Samples obtained from the Ohio and Missouri Agricultural Experiment Stations are identical with Red May. It was reported in 1919 from Illinois, Indiana, and Ohio.

Enterprise apparently is identical with Red May. It was obtained from the Indiana Agricultural Experiment Station, which received it from W. C. Betts, Forest, Ind. Its further history is undetermined. Enterprise wheat was reported from Hickman County, Ky., in 1919.

Jones Longberry is the name under which a sample of Red May was obtained from the Missouri Agricultural Experiment Station. It evidently is wrongly applied to this wheat, as the two varieties of Longberry wheat put out by A. N. Jones, of New York, are awned varieties.

May is now used most commonly as a synonym for Red May, although it probably was originally a white-kerneled wheat of earlier origin than Red May.

The name is also known to be used for other varieties. The distribution of May wheat was combined with Red May, as most correspondents used the names as synonymous.

Michigan Amber was grown on the eastern farm of the Pennsylvania Agricultural College, in Chester County, Pa., as early as 1871 (8, p. 134). Concerning the variety, the Farmers' Advocate, London, Ontario, published the following statement, which was republished in the Rural New Yorker in 1875 (11, p. 186-187) :

Michigan Amber, or Rappahannock, is of an amber color; growth and appearance otherwise resembling the Midge-proof variety.

Our samples of the variety are similar to Red May, with the possible exception of being a few days later in maturity. This might easily be due to the fact that Michigan Amber wheat has been grown farther north than the Red May for a period of nearly 50 years. Reported in 1919 from Arkansas, Illinois, Indiana, Kansas, Kentucky, Missouri, Ohio, Texas, and West Virginia.

Michigan Wonder was reported as one of the highest yielding wheats at the Missouri Agricultural Experiment Station in 1911 (146, p. 211). Our samples are the same as Red May, except that they are slightly more erect. It is reported grown in Michigan and Missouri.

Orange wheat was reported as having been introduced into Monroe County, N. Y., from Virginia in 1845 (102, p. 286). In 1857 Klippart (131) reported Orange wheat as a beardless, white-grained winter wheat grown in Ohio. The wheat now grown as Orange, however, has red kernels and apparently is identical with Red May. It is reported as one of the excellent-yielding beardless varieties of wheat for Missouri in 1910 (77, p. 67). Reported grown in Arkansas, Illinois, Kentucky, Missouri, and Oklahoma.

Pride of Indiana wheat obtained from the Indiana and Missouri Agricultural Experiment Stations is the same as Red May. The origin of the wheat is undetermined. Possibly the name became used for wheat through error, as it is a name of an important variety of corn in Indiana. It was reported in 1919 as grown in Indiana and Pennsylvania.

Red Amber is a name used by growers for Red May or Michigan Amber. A sample of Red Amber identical with Red May was obtained from Georgia in 1919.

The name Red Cross is sometimes wrongly applied to Red May wheat. Since 1893 the John A. Salzer Seed Co., seedsmen, of La Crosse, Wis., have been selling a wheat under the name Red Cross which is apparently identical with Red May. They bought the seed from a J. J. Barron, who claimed to have originated it (163, p. 17). This he states was done by crossing three varieties. No evidence is given, however, to prove that the crosses were made.

Red Republic and Republican Red are names used by growers for the Red May or Michigan Amber wheat in Illinois, Missouri, and Tennessee. Samples under these names were obtained from Illinois and Missouri in 1919.

ILLINI CHIEF.

Description.—Plant winter habit, midseason to late, tall; stem purple, strong; spike awnless, oblong, middense, erect to inclined; glumes glabrous, brown, midlong, midwide; shoulders wide, usually square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns few, 3 to 10 mm. long; kernels red, short to midlong, soft, ovate; germ mid-sized; crease wide, middeep to deep; cheeks usually angular; brush mid-sized, midlong.

Illini Chief is very similar to Red May, but differs slightly in being taller and later. It was originally mixed with Jones Winter Fife and with pubescent brown-glumed strains, most of which were heterozygous. Illini Chief is reported to be very resistant to Hessian fly injury.

History.—Illini Chief wheat was first distributed in the fall of 1915, by E. L. Gillham, Edwardsville, Ill. He advertised the variety as resistant to Hessian fly, stating "that it does practically resist Hessian fly attack." (95.)

Further history of Illini Chief wheat is recorded as follows:

Ed. Gillham, who was the first man to grow the wheat, bought the seed nine years ago from a neighbor by the name of Finley, and it is still known as Finley wheat in Madison County (31, p. 5).

Finley was reported in 1919 from Kansas, Missouri, and Ohio. The name Finley was in use in the early eighties for an awnless variety with white, glabrous glumes and red kernels (81, p. 29). This wheat apparently has now gone out of cultivation.

A second article in the *Prairie Farmer* by Dr. S. A. Forbes (90), State Entomologist of Illinois, contains the following sentence: "Mr. Gillham has traced his original stock to an Ohio farmer, who called it 'Early Carlyle.'" No wheat was reported under this latter name in the survey.

Distribution.—Grown as Illini Chief in Illinois and Missouri and as Finley in Kansas and Ohio.

Synonyms.—Early Carlyle and Finley.

RED CLAWSON (EARLY RED CLAWSON).



FIG. 46.—Outline map of the northeastern United States, showing the distribution of Red Clawson wheat in 1919. Estimated area, 80,900 acres.

Description.—Plant winter habit, midseason, midtall; stem purple, strong; spike awnless, oblong to linear clavate, middense, erect to inclined; glumes glabrous, brown, midlong, midwide; shoulders midwide to wide, usually

square, sometimes rounded or oblique; beaks midwide, obtuse, 0.5 to 1.0 mm. long; apical awns few, 5 to 15 mm. long; kernels pale red, midlong, soft, ovate to elliptical; germ small to midsized; crease midwide, shallow to middeep; cheeks rounded to angular; brush midsized, midlong.

Differs from Red May in being later and in having a slightly longer and more clavate spike, narrower glumes, and a longer kernel. Spikes, glumes, and kernels of Red Clawson wheat are shown in Plate XXX, A.

History.—Red Clawson was originated in 1888 as the result of a cross between Clawson, a white wheat, and Golden Cross, made by A. N. Jones, of Newark, Wayne County, N. Y. (58). It was advertised and distributed by Peter Henderson & Co. (110), seedsmen, of New York City, as early as 1889.

Distribution.—Grown in Idaho, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, West Virginia, and Wisconsin. (Fig. 46.)

Synonyms.—Clawson, Early Red Clawson, and Zeller's Valley. The name Clawson properly is applied only to the white-kerneled wheat which was one parent of the Red Clawson, but sometimes is used for Red Clawson. Zeller's Valley is the name under which a sample of wheat nearly identical with Red Clawson was obtained in 1919 from Sharpsburg, Md., where it was reported the variety had been grown for 40 years.



RED CLAWSON (A).

ROCHESTER (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



SILVERCOIN (A).

TRIPLET (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

ROCHESTER (ROCHESTER RED).

Description.—Plant winter habit, midseason, midtall; stem purple, strong, stout; spike awnless, very clavate, dense, erect; glumes glabrous, brown, midlong to long, midwide; shoulders wide, oblique to square; beaks midwide, obtuse, 0.5 to 1 mm. long; apical awns several, 3 to 20 mm. long; kernels red, small to midlong, soft, ovate, humped; germ small; crease midwide, middeep, pitted; cheeks rounded; brush midsized, midlong to long.

Rochester wheat has an extremely dense, clavate spike which distinguishes it from most other varieties. Spikes, glumes, and kernels of Rochester wheat are shown in Plate XXX, B.

History.—The origin of this variety is undetermined. It was advertised by Henderson (110) as early as 1891.

Distribution.—Grown as Rochester Red in Monroe County, N. Y., and as Pride of the Valley in Morris County, N. J.

Synonyms.—Pride of the Valley and Shepherd's Tennessee Fultz. A wheat called Pride of the Valley, identical with Rochester, was obtained from Morris County, N. J., in 1919, where it had been grown for eight years. Shepherd's Tennessee Fultz is of undetermined origin. A sample under this name, but apparently identical with Rochester, was obtained in 1912 from the Cornell University Agricultural Experiment Station, which had received it from Indiana. It is not known to be commercially grown.

RED CHIEF (EARLY RED CHIEF).

Description.—Red Chief is nearly identical with Rochester, but the spike is not quite as dense.

History.—Early Red Chief is reported by Henderson (110, 1903) to have originated from Early Red Clawson and Red Arcadian. By whom it was originated is not stated.

Distribution.—This variety is not known to be grown commercially at the present time. Samples were obtained from the Cornell University Agricultural Experiment Station.

SCHLANSTEDT (RIMPAU'S RED SCHLANSTEDTER SOMMERWEIZEN).

Description.—Plant spring habit, late, tall; stem very glaucous before maturity, white, midstrong; spike awnless, fusiform, sometimes nearly oblong, mid-dense, erect to inclined; glumes glabrous, brown, midlong, midwide; shoulders wanting to midwide, oblique; beaks wide, incurved, acute, 1 mm. long; apical awns few, 3 to 10 mm. long; kernels red, short to midlong, soft, ovate; germ midsized; crease narrow to midwide, shallow to middeep, triangular; cheeks angular; brush midsized, midlong.

This variety is distinguished from other brown-glumed, red-kerneled spring wheats by the glaucous stem and leaves.

History.—Schlandstedt is a spring form of wheat originated by Dr. Wilhelm Rimpau in 1889 at Schlanstedt, Germany, from a Bordeaux winter wheat (142, p. 192). A sample of this variety was introduced by the United States Department of Agriculture in 1909, but was not distributed. A field of the variety was found growing 9 miles north of Reardan, Wash., by a member of the Portland laboratory of the office of grain standardization, United States Department of Agriculture, in the summer of 1915. The history of its introduction is not known.

Distribution.—Grown to a very limited extent in Washington.

RESACA (RED RESACA).

Description.—Plant spring habit, midseason, midtall; stem purple, weak to midstrong; spine awnless, fusiform, narrow, middense, inclined; glumes glabrous, brown, midlong, narrow; shoulders narrow, oblique to square; beaks midwide, obtuse, 0.5 mm. long; apical awns few, 2 to 15 mm. long; kernels red, short, soft, ovate; germ small; crease midwide, shallow to middeep; cheeks rounded; brush mid-sized, short.

This variety is very similar to Odessa except in having a spring habit and purple straw and in being slightly earlier.

History.—The origin of Resaca wheat is not known. The sample described was obtained from C. P. Warner, Lake Victor, Tex., in 1919. He wrote as follows:

The pure Red Resaca was introduced in this county (Burnet County, Tex.) some 30 years ago by S. W. Shelburne, and has not been grown extensively. It perhaps does not produce as much as the Mediterranean.

Distribution.—Grown in Burnet County, Tex.

STANLEY.

Description.—Plant spring habit, midseason to late, tall; stem white, strong; spike awnless, fusiform, lax, erect, shatters; glumes glabrous, brown, midlong, narrow; shoulders wanting to narrow, oblique; beaks narrow, sometimes wanting, usually acute, 0.5 mm. long; apical awns few, 3 to 10 mm. long; kernels red, short to midlong, semihard to hard, ovate; germ mid-sized; crease midwide, shallow to deep, triangular; cheeks angular; brush mid-sized, midlong.

This variety differs from all other varieties of brown-glumed awnless winter and spring, red-kerneled wheats in having semihard to hard kernels.

History.—The Stanley originated about 1895 from the progeny of a cross made by Dr. William Saunders, Dominion cerealist, Ottawa, Canada. "The Stanley is a twin wheat with the Preston, both having had origin in the one kernel" (169, p. 14). "Parentage Ladoga (female) crossed with Red Fife (male)" (164, p. 219). An awned, white-glumed, white-kerneled winter wheat also has been grown under the name Stanley (204, p. 38).

Distribution.—Grown under irrigation in the Gallatin Valley of Montana and experimentally in Minnesota.

SILVERCOIN.

Description.—Plant winter habit, midseason, short to midtall; stem white, strong; spike awnless, clavate, dense, erect to inclined; glumes pubescent, white, midlong, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 1 mm. long; apical awns few, 3 to 10 mm. long; kernels white, short to midlong, soft; ovate to oval; germ mid-sized; crease midwide, middeep; cheeks angular to rounded; brush mid-sized, midlong.

Spikes, glumes, and kernels of Silvercoin wheat are shown in Plate XXXI, A.

History.—According to Mr. M. L. Peterson, Mendon, Cache County, Utah, Silvercoin wheat originated in a dry-land field of mixed Goldcoin and Sonora, belonging to Eph. Hansen, a few miles from Mendon, about 1900. The wheat was selected, increased, and distributed and became known as Eph. Hansen wheat, but the name later was changed to Silvercoin, though when and by whom is not known. The variety probably is the result of a natural field hybrid between Goldcoin and Sonora.

Distribution.—Grown in Boxelder and Cache Counties, Utah.

Synonym.—Hansen. As stated above, Hansen is the name of the man who is said to have originated Silvercoin wheat. The variety is still known as Hansen by some growers in Cache County, Utah.

JUMBUCK.

Description.—Plant spring habit, midseason, midtall; stem white, strong; spike awnless, oblong-fusiform, middense, erect; glumes pubescent, white, midlong, midwide to wide; shoulders wide, usually square; beaks midwide, acute, 0.5 to 1 mm. long; apical awns few, 3 to 20 mm. long; kernels white, short to midlong, semihard to hard, ovate; germ midsize; crease midwide, middeep to deep; cheeks rounded; brush midsize, midlong.

History.—Jumbuck is one of William Farrer's Australian varieties, produced by hybridization. Its origin has been recorded as follows:

Improved Fife	×	Tardent's Blue.
Unnamed	×	Lambrigg Australian Talavera.
Jumbuck.		

It received its name "Jumbuck" (a country name for a sheep) because of the woolly appearance of its chaff (188, p. 284.)

This variety was introduced into the United States about 1911 from New South Wales by the California Agricultural Experiment Station.

Distribution.—Grown in experiments by the California Agricultural Experiment Station and said to be commercially grown to a small extent in California.

INDIAN.

Description.—Plant spring habit, early, short; stem white, weak to midstrong; spike awnless, oblong, dense, erect; glumes pubescent, white, midlong, midwide, easily shattered; shoulders narrow, oblique to elevated; beaks narrow, acuminate, 1 to 3 mm. long; apical awns several, 3 to 5 mm. long; kernels white, short, soft, ovate to oval; germ small; crease midwide, shallow; cheeks usually rounded; brush small, short.

Indian differs from Sonora only in having white instead of brown glumes.

History.—The origin of Indian wheat is not definitely known. It probably is the result of a natural field hybrid between Sonora and some other variety. It is a common mixture in the Sonora variety, although it has been separated and grown by itself for many years. George L. Little, jr., of Morgan, Morgan County, Utah, reported in 1917 that the origin of the variety was not known, but that it had been grown in his county for 40 or 50 years.

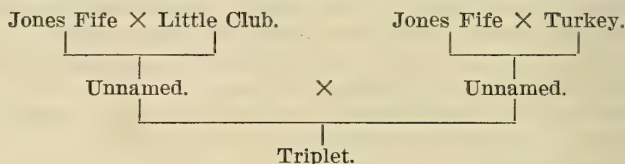
Distribution.—Grown to a limited extent in Arizona and in Summit and Morgan Counties, Utah.

TRIPLET.

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awnless, oblong-fusiform, middense, inclined; glumes pubescent, white, midlong, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns few, 3 to 8 mm. long, sometimes incurved throughout spike; kernels red, short to midlong, semihard, ovate; germ small; crease narrow to midwide, shallow; cheeks rounded; brush small, midlong.

Triplet differs from Jones Fife in being slightly shorter and earlier and in having a harder kernel with a smaller germ and rounded rather than angular cheeks. Plate XXXI, *B*, shows spikes, glumes, and kernels of the Triplet variety.

History.—Triplet was originated at the Washington Agricultural Experiment Station, Pullman, Wash., from a combination of crosses in which Jones Fife, Little Club, and Turkey were used as parents. Its pedigree is as follows:



It was first grown as a pure strain in 1910 and was distributed for commercial growing in 1918, after it had proved to be a high-yielding variety in nursery and plat experiments at Pullman.

Distribution.—Grown at experiment stations in the Pacific Northwest and commercially in Oregon and Washington in 1920.

MEALY.

Description.—Plant winter habit, midseason, midtall to tall; stem white, midstrong to strong; spike awnless, oblong-fusiform, middense, inclined; glumes pubescent, white, midlong, midwide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns few, 3 to 10 mm. long; kernels red, midlong, semihard, ovate; germ midsized; crease wide, deep; cheeks angular; brush large, long.



FIG. 47.—Outline map of a portion of the eastern United States, showing the distribution of Mealy wheat in 1919. Estimated area, 65,500 acres.

Mealy differs from Triplet in being slightly taller and later, with stronger stems and in having kernels with more angular cheeks and larger and longer brush. Kernels, spikes, and glumes of Mealy wheat are shown in Plate XXXII, *A*.

History.—This variety was distributed by the United States Department of Agriculture in 1885, and for several years thereafter, and the following record of its origin accompanied the seed:

Originated by M. A. Mealy, in 1880, by planting the kernels of three heads of wheat selected from a growing crop of Fultz. It is similar to other varieties known as White Velvet Chaff; is of fair promise and is said to excel the Fultz in yield and flouring qualities (57, p. 19).

Distribution.—Grown in Alabama, Georgia, Indiana, Kentucky, Missouri, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and West Virginia. (Fig. 47.)

Synonyms.—Velvet Chaff, Velvet Head, White Velvet Chaff.

Velvet Chaff and Velvet Head are common farm names for Mealy wheat. White Velvet Chaff was the name of a wheat grown previous to the origin of Mealy, but the varieties probably were identical. The wheat evidently has disappeared from cultivation under this name.



MEALY (A).

JONES FIFE (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



HAYNES BLUESTEM (A).

GALGALOS (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

JONES FIFE (JONES WINTER FIFE).

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awnless, oblong-fusiform, middense, nodding; glumes pubescent, white, midlong, midwide to wide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns few to several, lower ones often incurved, 3 to 8 mm. long; kernels red, short to midlong, soft to semihard, ovate, humped; germ mid sized, abrupt; crease midwide to wide, middeep to deep; cheeks angular; brush mid sized, midlong.

This variety differs from Mealy principally in having a nodding spike and a softer kernel. It makes a comparatively weak flour for bread making. Spikes, glumes, and kernels of Jones Fife wheat are shown in Plate XXXII, B.

History.—Jones Fife (Jones Winter Fife) was originated by A. N. Jones, of Newark, Wayne County, N. Y., in 1889.¹⁰ According to Carleton (61, p. 221), "it descended from Fultz, Mediterranean, and Russian Velvet."

Distribution.—Grown as Fife, Jones Fife, or Jones Winter Fife in Idaho, Illinois, Indiana, Iowa, Kentucky, Michigan, Missouri, Montana, Ohio, Pennsylvania, Utah, Virginia, Washington, and West Virginia, and as synonyms in Colorado and Wyoming. This distribution is shown in Figure 48.



FIG. 48.—Outline map of the northern United States, showing the distribution of Jones Five wheat in 1919. Estimated area, 476,100 acres.

Synonyms.—Burbank's Super, Canadian Hybrid, Crail Fife, Fife, Fishhead, Silver King, Super, Velvet Chaff, Winter Fife.

Burbank's Super, or Super wheat, was first distributed by Luther Burbank, of Santa Rosa, Calif., in the fall of 1917. The following is Mr. Burbank's first statement regarding this variety, published in August, 1917, in his catalogue under the title "The New Burbank Wheat" (51):

It is with unusual satisfaction that I now offer for the first time a limited quantity of my new wheat; the best result of 10 years of most careful and expensive experiments. It has been tested alongside of 68 of the best wheats of the world, and has excelled them all in yield, uniformity, and other desirable characteristics; the growth is strong, 4 feet on good ordinary soil, tillers unusually well, and on ordinary valley soil, without special cultivation, care, or fertilizing, this summer produced at the rate of forty-nine and 88-100 bushels per acre, every plant and every kernel uniform, as this wheat was originally all grown from one single kernel. Even at present prices of ordinary wheat for milling purposes, it will be readily seen that the crop of each acre would purchase an acre of the best wheat land.

The small field of this new wheat has been the wonder and surprise of thousands who have seen it, nothing like it in uniformity and beauty ever having been seen before. The cut shows the exact size and appearance of the long, smooth, white, well-filled heads. Every kernel is guaranteed uniform and correct to type.

¹⁶ Printed stationery of A. N. Jones.

This, like all other wheats grown in California, is a winter wheat and should probably be generally treated as such, and will, no doubt, thrive better in new localities after it becomes acclimated by one or two seasons' growth. . . . The best successes of my customers are also my own, and the whole wheat crop of America will soon be enormously increased if this new "Burbank" wheat is generally sown.

The wheat was further advertised and distributed as Super wheat in 1917 and 1918 by Mr. Burbank. Apparently most of his stock was purchased and resold by the State Seed & Nursery Co., of Helena, Mont., at the price of \$5 per pound. They advertised it as a wheat adapted for both spring and fall sowing. It was distributed, therefore, in many sections where it was not adapted. East of the Rocky Mountains it generally winterkilled when fall sown and remained prostrate on the ground throughout the growing season when spring sown, thus resulting in failure. Its distribution, therefore, probably now is limited to the Pacific coast and the Intermountain areas. It was not reported in the varietal survey of 1919. The writers have found Super wheat to be identical with Jones Fife in all taxonomic characters, as well as in yield and in milling and baking quality.

Canadian Hybrid is similar to Jones Fife, except that it sometimes has a slightly longer and laxer spike. It was listed by John A. Salzer, seedsman, of La Crosse, Wis., as early as 1895. Concerning it he states that "it originated in Canada, on the farm of Clark Parker, through crossing, or in the words of the grower, 'I have long had the best crops of winter wheat in my section. I would take the best specimens of different sorts, and plant them together, and thus continuously improve my yield. Now, I can not call any of these sorts pure, because obtained as above, but can call the Canadian Hybrid enormously productive.'" (163, p. 16, 1900.) It was reported grown in Illinois, Indiana, Michigan, and Missouri.

Crail Fife is a local name applied to Jones Fife wheat in Montana, Frank Crail, of Bozeman, Mont., being the farmer who grew and distributed the variety under that name. Fishhead is a wheat similar to Jones Fife, samples of which have been obtained from the Cornell University Agricultural Experiment Station. Silver King is a name used for Jones Fife in Colorado and Wyoming. According to J. B. Hill, of Westridge, Colo., it has been grown in that vicinity for 16 or 18 years. The name Velvet Chaff has been used for Jones Fife, as for several other varieties, by many growers. Winter Fife, a part of the original name, often is used by growers to distinguish it from the well-known spring wheat called Fife.

HAYNES BLUESTEM.

Description.—Plant spring habit, late, midtall to tall; stem white, glaucous before maturity, midstrong to strong; spike awnless, narrowly fusiform, mid-dense to lax, inclined; glumes pubescent, white, short, midlong, narrow, often shattering; shoulders midwide, oblique to square; beaks midwide, obtuse, 0.5 mm. long; apical awns few, 3 to 15 mm. long; kernels red, short to midlong, hard, ovate; germ mid-sized; crease narrow, middeep to deep; cheeks rounded; brush midsize, midlong to long.

This variety is distinct among the hard spring-wheat varieties because of being pubescent. It is very susceptible to stem rust. When rust is not present it yields well under humid conditions. It is an excellent milling and bread-making wheat. Spikes, glumes, and kernels of Haynes Bluestem are shown in Plate XXXIII, A.

History.—Haynes Bluestem was first developed through selection by L. H. Haynes (107), of Fargo, N. Dak., about 1895. He recorded the following information concerning its previous origin and his work toward its improvement:

The wheat now grown in the Northwest, ordinarily known as a Bluestem, was grown 40 years ago (1855) in some Eastern States as a Red Winter wheat. Being semihard when grown in the East, since being changed into a spring wheat and grown in the hard-wheat district of the Northwest, it is now hard and the berry as beautiful an amber as can be found. . . .

In 1882 a friend recommended this wheat to me so highly that I was induced to try it. I bought some and sowed it that year, and grew it again in 1883. I was much pleased with its strong growth and good yield, but one difficulty had to be overcome. It evidently had not had the necessary care to keep it pure and had become mixed with soft and bearded wheats, which rendered it quite objectionable for sowing. To overcome this objection I resolved to grow it pure, knowing that it would take years to do it, yet I thought it would repay the time and trouble in the end. I accordingly commenced by planting in my garden in 1884 the grains from two good heads, having three kernels abreast, hoeing it as it grew. While it was growing, in studying over the matter I came to the conclusion that "blood would tell" in the vegetable as well as the animal kingdom by propagating from the best.

From the product of these two heads I rejected the latest and poorest heads, using only the best and earliest for use upon my trial grounds. . . .

The trial grounds are planted each year with wheat from the choicest heads of the previous year and cultivated, the product being carefully selected, head by head, and the crop, except what is necessary to replant the ground, is sown with the field grain, thereby causing gradual improvement from year to year.¹⁷

Mr. Haynes distributed this wheat widely throughout the Dakotas and Minnesota for several years, starting about 1892. As shown in this history, Bluestem wheat was grown in the Dakotas before Mr. Haynes originated his strain. As he has recorded, it probably was grown in the eastern United States as a winter wheat before being grown as a spring wheat in the Northwest. Haynes Bluestem wheat was further improved by the Minnesota Agricultural Experiment Station. A pure-line selection, first known as Minnesota No. 169, was developed and distributed by that institution in the late nineties (109, p. 69-72). This strain also has been known as Haynes Bluestem, and is now the principal strain grown under that name. The name Bluestem now is most commonly used for this whole group of Bluestem wheats and also as a farm name for the variety. This is correct in some cases. As the original Bluestem and the strains and pure lines can not be distinguished from each other, the name Haynes Bluestem is used here to distinguish this wheat from five other important varieties of wheat commonly known as Bluestem in the United States and to retain its identity with the old and well-known name Bluestem.

Distribution.—Grown principally as Bluestem in Illinois, Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota, South Dakota, Wyoming, and Wisconsin. Figure 49 shows the distribution of this variety.

Synonyms.—Bluestem, Bolton Bluestem, Marvel Bluestem, Minnesota No. 169, Velvet Bluestem. As shown above, Bluestem was the earliest and is still the most commonly used name for Haynes Bluestem wheat. Bolton Bluestem was obtained originally from Thomas Bolton, of Park River, N. Dak., by the North

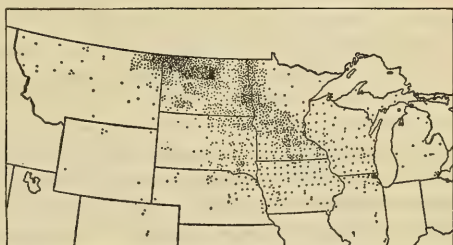


FIG. 49.—Outline map of the north-central United States, showing the distribution of Haynes Bluestem wheat in 1919. Estimated area, 1,530,800 acres.

¹⁷ The pamphlet was borrowed from Walter R. Reed, of Amenla, N. Dak.

Dakota Agricultural Experiment Station. It was first grown at that station in 1893. As far as known it was a mass variety. Marvel Bluestem is a name which was applied to Bluestem wheat by J. A. Salzer & Co., seedsmen, of La Crosse, Wis. It is known to have been used at least as early as 1892. Marvel Bluestem was reported in 1919 from Minnesota, South Dakota, and Wisconsin. Minnesota No. 169, as shown above, is a pure-line selection of Haynes Bluestem, developed at the Minnesota Agricultural Experiment Station. Velvet Bluestem is a name used by Carleton (58, p. 65-66) for the bulk unselected Bluestem wheat grown in the Northwest.

DAKOTA.

Description.—This variety also is identical with Haynes Bluestem in all morphological characters, but has outyielded it in North Dakota.

History.—The Dakota is a pure-line selection from the original Haynes Bluestem, originated at the North Dakota Agricultural Experiment Station about 1898. It was first called by its number, North Dakota No. 316, later by the name Select Bluestem, and finally was named Dakota.

Distribution.—It was widely grown in North Dakota about a decade ago, but now probably has largely disappeared from cultivation.

Synonyms.—North Dakota No. 316, Select Bluestem.

GALGALOS.

Description.—Plant spring habit, although remaining prostrate during its early growth, midseason, midtall; stem white, slender, weak; leaves pubescent, glaucous; spike awnless, fusiform, lax, inclined; glumes pubescent, light brown, long, midwide; shoulders midwide, oblique to square; beaks wide, acute 1 to 2 mm. long; apical awns many, 3 to 30 mm. long; kernels white, midlong, soft, ovate to elliptical, slightly humped, ventral side rounded; germ small; crease narrow, shallow; cheeks usually rounded; brush mid-sized, midlong.

This variety is distinguished by its pubescent, brown glumes and pubescent leaves. It is a high-yielding wheat in dry climates and is one of the best white wheats for bread baking. Its weak straw, however, is a serious objection. Spikes, glumes, and kernels of Galgalos wheat are shown in Plate XXXIII, B.

History.—Galgalos (S. P. I. No. 9872) was introduced in 1903 by the United States Department of Agriculture (197) from the Erivan Government in Transcaucasian Russia,

Distribution.—Grown in Kings, Lassen, Merced, San Luis Obispo, and Shasta Counties, Calif.; and Crook, Grant, Jefferson, Josephine, and Wallowa Counties, Oreg.

Synonyms.—Russian Red, Velvet Chaff. Russian Red is a local name used for Galgalos in Shasta County, Calif., and Velvet Chaff is a local name used for it in Josephine County, Oreg.

SONORA.

Description.—Plant spring habit, early, short to midtall; stem white, strong; spike awnless, oblong, short, dense, erect; glumes pubescent, brown, midlong, midwide, easily shattered; shoulders narrow, usually oblique; beaks narrow, acuminate, 1 to 3 mm. long; apical awns several, 3 to 8 mm. long; kernels white, short, soft, ovate to oval; germ small; crease midwide, shallow; cheeks rounded; brush small, short.

This variety is distinct and peculiar because of its long acuminate beaks. It is usually a poor-yielding variety except in southern California and Arizona, where it appears well adapted. It produces a weak flour, which is mostly used for pastry. Spikes, glumes, and kernels of Sonora wheat are shown in Plate XXXIV, A.

History.—Sonora was brought to the United States from Magdalena Mission, northern Sonora, Mexico, where it has been grown for 150 years.¹⁸ It is known to have been grown in the United States for about 100 years, as it is the wheat grown by the Pima and Yuma Indians in Arizona. Several samples of wheat, similar to Sonora, have recently been introduced by the United States Department of Agriculture from South Africa.

Distribution.—Grown in Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming. (Fig. 50.)

Synonyms.—Ninety-Day, Red Chaff, White Sonora. Ninety-Day is a local name of Sonora wheat in Millard County, Utah, while Red Chaff and White Sonora are names commonly used for it by growers in Idaho and in Utah.



FIG. 50.—Outline map of the western United States, showing the distribution of Sonora wheat in 1919. Estimated area, 243,900 acres.

GRANDPRIZE (ST. LOUIS GRAND PRIZE).

Description.—Plant winter habit, midseason to late, short; stem white, strong; spike awnless, clavate, dense, inclined; glumes pubescent, brown, mid-long, wide; shoulders midwide, oblique to square; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns several, 3 to 15 mm. long; kernels red, midlong, soft to semihard, broadly ovate to oval; germ mid-sized; crease usually wide, deep, pitted; cheeks rounded to angular; brush large, midlong to long.

The Grandprize wheat is usually not uniform in shape of spike, a small percentage of oblong spikes usually being present. Spikes, glumes, and kernels of Grandprize wheat are shown in Plate XXXIV, B.

History.—Grandprize (St. Louis Grand Prize) was originated by A. N. Jones, of Le Roy, N. Y., between the years 1900 and 1908. It was distributed by Peter Henderson & Co. (110), seedsmen, of New York City, in 1910. The wheat derived its name from the fact that Mr. Jones received a grand prize for his cereal exhibit at the St. Louis Exposition in 1904.

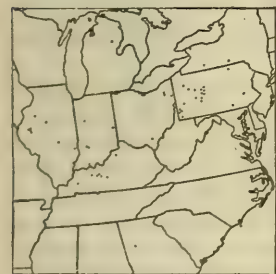


FIG. 51.—Outline map of a portion of the eastern United States, showing the distribution of Grandprize wheat in 1919. Estimated area, 34,100 acres.

Distribution.—Grown in Georgia, Illinois, Indiana, Kentucky, Michigan, New York, Ohio, and Pennsylvania. (Fig. 51.)

¹⁸ Verbal statement of Prof. W. W. Mackie, January 22, 1919.

Synonyms.—Bull Moose, Golden Chaff, New Genesee, and Velvet Head.

Bull Moose is a recent and local name used for Grandprize wheat in Crawford County, Ill. Golden Chaff is a name used for Grandprize in Indiana. New Genesee is the name under which a wheat similar to Grandprize was obtained from the Wisconsin Agricultural Experiment Station, Madison, Wis., in 1917. Its origin is undetermined. This sample was not pure. It contains a greater percentage of the form having oblong spikes than does Grandprize itself. New Genesee is not known to be commercially grown. Velvet Head is a name under which Grandprize wheat was reported from Kentucky.

DEMOCRAT.

Description.—Plant winter habit, midseason, tall; stem white, strong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders wanting to narrow; beaks 1 to 3 mm. long; awns 3 to 6 cm. long; kernels white, midlong, soft, ovate, acute; germ small to mid-sized; crease usually narrow, shallow to middeep; cheeks angular; brush small, midlong.

Democrat is the only variety of winter wheat having awned white-glumed fusiform spikes and mid-sized white kernels.

History.—The origin of Democrat wheat is undetermined. It was grown by the Ohio Agricultural Experiment Station as early as 1883. It was obtained by that station from George Burr, of Lodi, Ohio, and at that time was recorded as being a variety quite generally grown in Ohio (80, p. 17).

Distribution.—Grown sparingly in Illinois, New York, Ohio, Pennsylvania, and West Virginia.

SENECA CHIEF.

Description.—Plant winter habit, late, short to midtall; stem white, midstrong, stout; spike awned, clavate, dense, inclined; glumes glabrous, white, midlong, midwide; shoulders wanting to narrow, rounded; beaks 3 to 20 mm. long; awns 3 to 7 cm. long; kernels white, short, soft, broadly ovate to oval; germ mid-sized; crease midwide, shallow; cheeks usually rounded; brush mid-sized, midlong.

Seneca Chief, as described above, differs from Oatka Chief in being shorter and in having a shorter and denser spike, longer beaks, and smaller kernels.

History.—The origin of Seneca Chief is not determined. It was reported by Carleton in 1900 as a wheat of American origin (58, p. 54). It was listed by the Ohio Agricultural Experiment Station for the first time in 1888 (81, p. 29), but at that time was described as an awned, brown-glumed, red-kerneled variety similar to Diehl-Mediterranean. This may be the correct description for Seneca Chief, and the variety grown by the writers may possibly be the old Diehl wheat which is known to have been of this type.

Distribution.—Seneca Chief as described above was formerly grown in New York, but is not now known to be grown commercially. It is being grown at several experiment stations.

OATKA CHIEF.

Description.—Plant winter habit, late, midtall; stem white, strong, stout; spike awned, linear-clavate, inclined; glumes glabrous, white, midlong, midwide; shoulders narrow, usually rounded; beaks 2 to 10 mm. long; awns 3 to 6 cm. long; kernels white, short to midlong, soft, ovate to elliptical; germ mid-sized; crease midwide, middeep; cheeks usually rounded; brush mid-sized, midlong.



SONORA (A).

GRANDPRIZE (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



OATKA CHIEF (A).

PALISADE (B).

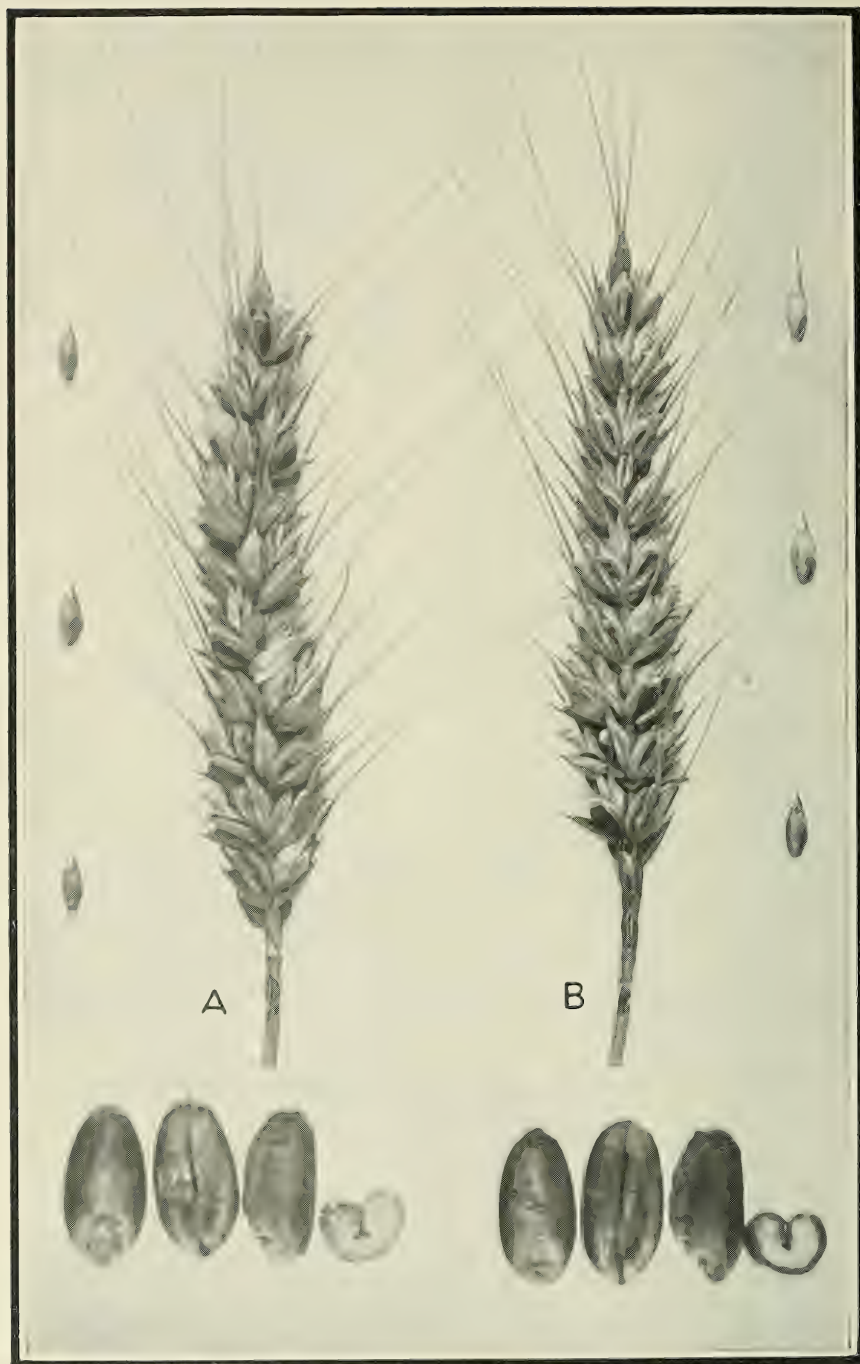
Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



PROPO (A).

BAART (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



GIPSY (A).

VALLEY (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

A spike, glumes, and kernels of Oatka Chief are shown in Plate XXXV, A.

History.—Oatka Chief was originated by A. N. Jones, of Newark, Wayne County, N. Y., in 1896.¹⁹

It was distributed by Henderson (110, p. 73) in 1897. In 1905 it was listed by the Ohio Agricultural Experiment Station as a red-kerneled wheat (204, p. 38). This was evidently an error, however, or else this station had a different wheat.

Distribution.—This variety probably now has disappeared from commercial cultivation. It is still grown at several of the eastern experiment stations.

MAMMOTH AMBER (JONES MAMMOTH AMBER).

Description.—Plant winter habit, late, midtall; stem purple, strong, stout; spike awned, clavate, middense to dense, erect to inclined; glumes glabrous, white, midlong, midwide; shoulders narrow, usually oblique; beaks 2 to 15 mm. long; awns 3 to 6 cm. long; kernels white, midlong, soft, ovate; germ midsized; crease narrow to midwide, shallow to middeep; cheeks usually rounded; brush midsized, midlong.

This variety differs from the Seneca Chief and Oatka Chief principally in having purple stems.

History.—This variety also was originated by A. N. Jones (127). He has recorded its history as follows:

This fine variety of wheat originated from crossbreeding my American Bronze, known in many sections as No. 8 (its trial-bed number). This cross was crossbred with Early Genesee Giant.

Jones Mammoth Amber was advertised and distributed by Peter Henderson & Co. in 1906.

Distribution.—This wheat is not known to be commercially grown at the present time.

PALISADE (WHITE PALISADE).

Description.—Plant spring habit, midseason, midtall; stem white, weak, slender; spike awned, fusiform, middense, inclined to nodding; glumes glabrous, white, midlong, narrow; shoulders wanting to narrow, oblique; beaks 2 to 4 mm. long; awns 3 to 7 cm. long; kernels white, midlong, soft, ovate to elliptical; germ small; crease narrow to midwide, shallow; cheeks rounded to angular; brush midsized, short.

A spike, glumes, and kernels of Palisade are shown in Plate XXXV, B.

History.—White Palisade wheat was obtained by the North Platte substation, North Platte, Nebr., from a farmer in the vicinity of Palisade, Nebr., about 1907. The previous history of the variety is undetermined. The White Oregon variety, which appears to be synonymous, was grown in the central part of the United States many years ago.

Distribution.—Grown under the names of synonyms in Colorado, Nebraska, and western Kansas.

Synonyms.—White Oregon and White Spring. Samples of White Oregon were obtained in Logan and Rawlins Counties, Kans., in 1919. The variety was reported in several other counties in Kansas as well. White Spring is a descriptive name for the Palisade variety used by many growers in Kansas and Nebraska.

¹⁹ Printed stationery of Mr. Jones.

PROPO.

Description.—Plant spring habit, early to midseason, midtall; stem faintly purple, midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks 2 to 5 mm. long; awns 3 to 7 cm. long; kernels white, midlong, soft, ovate to elliptical, slightly humped; germ small to midsized; crease midwide, middeep; cheeks rounded to angular; brush midsized, midlong.

Propo is distinct from the other wheats in the group in having a straw which is faintly purple. A spike, glumes, and kernels of this variety are shown in Plate XXXVI, A.

History.—This variety was first known as Proper, for which the following history was recorded in 1879 (156):

The Proper originated from the selection of a number of heads of bearded wheat in a field of Mr. Proper, at Sutter station, on the line of the Marysville & Vallejo Railroad, in Sutter County. Impressed with their appearance, Mr. Proper gathered and sowed, and sold to his neighbors, a very fine article of early wheat, eagerly sought after by millers, and which makes a superior article of flour. The Proper is a bearded wheat and exactly similar in appearance, as to the heads, to the Pride of Butte, although of entirely a different nature. . . . The Proper is a wheat which ripens very early—as early as the Sonora, one of the earliest known varieties. It is from five to eight days later, owing to peculiarities of soil in this respect. It is not a very good wheat to stool, and in this respect quite unlike the Pride of Butte. It is of rather soft straw, and in rich ground is liable to fall down and lodge, hence on such land it is better to sow in the spring, but not on poor land. It will stand later sowing and still mature earlier than any other variety I know of except Sonora (156).

The writers believe the above history is the true origin of the variety. The following later and somewhat different history of Propo also has been recorded by Shaw and Gaumnitz (176, p. 318), of the California Agricultural Experiment Station:

Of Propo, Mr. R. M. Shackleford, of Paso Robles, for many years connected with the milling trade of this State, is authority for the statement that this variety was a field selection from a sowing made from a shipment of wheat from Chile, the selection being sufficient in quantity to seed 30 acres of land in the Panoche Valley. From this 30 acres there was produced about 500 sacks of wheat. Mr. Shackleford writes:

"I purchased this wheat and shipped it to Mr. A. D. Starr, of Marysville. The name given to this wheat at the time I purchased it was 'Snowflake,' and I shipped it to him under that name. There was some little seed left in the country, and quite an inquiry arose for the same seed. Mr. Starr returned me two carloads—one in the Salinas Valley and one to Hollister. He reported to me the proper name was Propo. My memory is that was the name that was given to it at the time I purchased it, but old settlers tell me it was called 'Snowflake,' and that until it was returned from the north it was not known as 'Propo.' This leads me to believe that some of the original seed was distributed in the north and raised much as it was in San Benito County, and that it received the name Propo or Proper from the party who there grew it. My opinion is that this is a complete history of the introduction of Propo wheat into California."

Distribution.—Grown in Colusa, Monterey, Riverside, San Luis Obispo, Santa Barbara, and Sutter Counties, Calif.

Synonym.—Proper. This probably is the original name for the variety, but in recent years the name Propo has become most generally used.

TREADWELL.

Description.—Plant winter habit, midseason, tall; stem white, midstrong; spike awned, fusiform, middense, nodding; glumes glabrous, white, long, midwide, easily deciduous; shoulders wanting to narrow, oblique; beaks 3 to 15

mm. long; awns 3 to 7 cm. long; kernels white, long, soft, elliptical, acute; germ small to midsized; crease narrow, shallow; cheeks usually rounded; brush small, usually long.

The above description is for only one of several strains of Treadwell wheat.

History.—Treadwell wheat was recorded in the Rural New Yorker in 1868 as having originated "in Michigan and is probably a hybrid." Several other early references refer to Treadwell wheat as a mixed variety. An awnless white-kerneled strain and an awned red-kerneled strain had been developed from it as early as 1882. The awnless white-kerneled strain was known as Smooth Treadwell and the awned red-kerneled strain as Bearded Treadwell (81, p. 27). The original wheat is thought to have been mostly of the type described above.

Distribution.—Reported in 1919 from Oakland and Tuscola Counties, Mich. In Tuscola County it was described as above, while in Oakland County it was reported to be an awnless wheat, having white kernels.

BAAET (EARLY BAAET).

Description.—Plant spring habit, early, midtall to tall; stem white, midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, long, narrow; shoulders narrow, oblique to square; beaks 3 to 5 mm. long; awns 3 to 6 cm. long; kernels white, long, soft to semihard, ovate to obpyriform; germ small; crease narrow, shallow; cheeks usually rounded; brush midsized, short to midlong.

This variety can be distinguished from all others by the yellowish pear-shaped kernels. A spike, glumes, and kernels of Baart wheat are shown in Plate XXXVI, B.

History.—The Early Baart was received with four other varieties (197, S. P. I. No. 5978) from Australia by the United States Department of Agriculture in 1900. The commercial distribution of the variety in this country certainly is the result of this introduction. In Australia it has never been a leading commercial variety, although it has been grown by some farmers for many years. In recent introductions of wheat from South Africa varieties have been obtained which are identical with Early Baart. The name "Baart" is Dutch for bearded. It seems probable that the variety was introduced to Australia from the Orange River Colony or the Transvaal in South Africa and was originally of European origin (67, p. 3).

The variety probably was first distributed for commercial growing by the Arizona Agricultural Experiment Station, which obtained its original seed from the Office of Cereal Investigations, United States Department of Agriculture. The variety was well established in Arizona by 1914, when it was first grown in Washington, and later spread to Oregon, Idaho, and California.

Distribution.—Grown in Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, and Washington. (Fig. 52.)

Synonyms.—Arizona Baart, Columbia, Diener Hybrids, Diener No. 18, and White Columbia. Arizona Baart is a name often used for the variety, because it first became commercially established in Arizona. Columbia and White Columbia are local names used for Early Baart wheat in the vicinity of Fair-

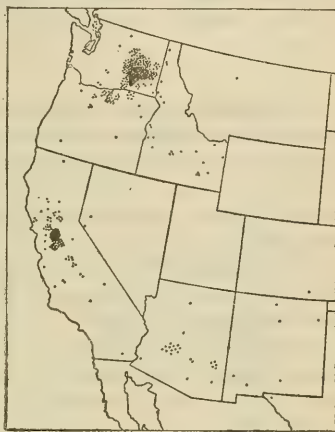


FIG. 52.—Outline map of the western United States, showing the distribution of Baart wheat in 1919. Estimated area, 500,500 acres.

field and Spangle, Wash. Diener Hybrids and Diener No. 18 are names under which Baart wheat was distributed by the Richard Diener Co., Kentfield, Calif. The so-called Diener Hybrids were first distributed in the fall of 1918. There were three similar strains known as Nos. 2, 16, and 18. Concerning Diener No. 18, Mr. Diener has written as follows:²⁰

This No. 18 was produced as follows: The original 50 berries were picked out of chicken feed and planted, but when the plants came up they showed no unusual qualities, being just common ordinary wheat. These 50 berries had been planted about 20 inches apart in the rows and the rows about 20 inches apart. About 30 plants lived and from the natural pollinization back and forth between these 30 plants the hybridization resulted. The important features of my process lie in the selection of the original 50 berries.

TALIMKA.

Description.—Plant spring habit, early, short; stem white, slender, weak; spike awned, fusiform, middense to lax, inclined; glumes glabrous, white, midlong, midwide, firm; shoulders narrow to midwide, oblique to apiculate; beaks 5 to 40 mm. long; awns 2 to 5 cm. long; kernels white, long, hard, ovate, slightly humped; germ small; crease midwide, shallow; cheeks angular; brush usually small, short.

This variety differs from Chul only in having white kernels. The kernels are large, hard, corneous, and greatly resemble those of durum wheats, except that the brush is longer.

History.—Talimka wheat was introduced from Russian Turkestan by the United States Department of Agriculture in 1904 (197, S. P. I. No. 10611) and also as a mixture in introductions of Chul. The name Talimka was not a part of the record of the introduction above cited, but was applied to the wheat about 1916, as it was identical with a later introduction from Russia which bore that name (C. I. No. 3717). A still later introduction under the name of Talimka was obtained from Russia (C. I. No. 5016), but this wheat proved to be similar to Ghirka.

Distribution.—Talimka wheat is grown at experiment stations in the Pacific coast areas, but not commercially except as a mixture in Chul.

Synonym.—Saumur. This variety is identical with Talimka. It was introduced by the United States Department of Agriculture in 1903 from France, where it has been grown for many years.

NEBRASKA NO. 28.

Description.—Plant winter habit, early, short; stem white, midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide, easily deciduous; shoulders narrow to midwide, oblique to square; beaks 2 to 5 mm. long; awns 2 to 5 cm. long; kernels red, short to midlong, soft to semihard, ovate, slightly humped; germ small; crease narrow to midwide, shallow; cheeks rounded; brush midsized, midlong.

Nebraska No. 28 resembles Turkey somewhat, but usually is about 6 inches shorter, ripens from 7 to 10 days earlier, has softer kernels, and shatters more easily.

History.—This wheat is the result of a cross between Big Frame and Turkey, made in 1902 by either T. L. Lyon or Alvin Kezer at the Nebraska Agricultural Experiment Station. The Turkey variety was probably the male parent. Number 28 is a selection from the progeny made by Montgomery, which was later further selected and thoroughly tested by Kiesselbach.

²⁰ Correspondence with the Office of Cereal Investigations, dated Aug. 28, 1918.

Distribution.—This strain was distributed in 1916 by the Nebraska Agricultural Experiment Station for testing at other stations and for commercial growing in Nebraska. It is now grown by a number of experiment stations in the United States, and doubtless to some extent by farmers in Nebraska. None of this variety was reported in the survey of 1919.

Synonymy.—Nebraska Hybrid is the name used by several experiment stations where the variety is grown.

GLADDEN.

Description.—Gladden is similar to Gipsy, but can be distinguished from it by its shorter beaks, which usually do not exceed 3 mm. It also has stronger stems and is superior to Gipsy in yield and quality.

History.—The following history of the Gladden wheat has been reported by Prof. C. G. Williams (206), of the Ohio Agricultural Experiment Station, where the variety originated:

The Gladden wheat originated from a single head of wheat selected from a field of Gipsy wheat in 1905, and was first grown in 1906 under the number 6100, along with other head rows of Gipsy, Fultz, Poole, and other varieties. It has many of the characteristics of the Gipsy wheat, being bearded, having a white chaff and red kernel.

In consulting the old notebooks of 14 years ago I find it described as "very erect" in growth, the words being underscored, and given the highest rank for stiffness of straw of any of the Gipsy rows, and as high a rank as any row in the test. The photographs taken in 1907, 1910, and 1915 show more than ordinary stiffness of straw.

In so far as yield is concerned, it had to stand high from the start or be cast aside. A vast majority of the heads tested were weeded out each year on account of ordinary yield. In milling and baking tests in 1915 the Gladden showed superior qualities.

This variety passed along under the number name, 6100, until 1915, when it seemed best to give it a real name in order to prevent confusion, as it was being distributed quite a little over the State. It was named for Washington Gladden, a man not associated with agriculture particularly, but the most useful citizen Ohio had for many years.

Distribution.—Grown in many parts of Ohio.

GIPSY.

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spikes awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to square; beaks 2 to 10 mm. long; awns 3 to 7 cm. long; kernels red, midlong, soft to semihard, ovate, humped; germ mid-sized; crease midwide, shallow to middeep, pitted; cheeks usually rounded; brush small, midlong.

A spike, glumes, and kernels of Gipsy wheat are shown in Plate XXXVII, A.

History.—The origin of Gipsy wheat is undetermined. It was grown in Missouri as early as 1877 (14) and at the Ohio Agricultural Experiment Station by 1888 (81, p. 28). There is a tradition that the name was given the variety because it was first obtained from a gipsy.

Distribution.—Grown in Arkansas, Delaware, Illinois, Indiana, Kansas, Kentucky, Michigan, Missouri, New Jersey, Ohio, Pennsylvania, Virginia, and West Virginia. (Fig. 53.)

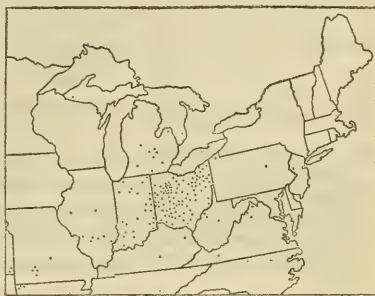


FIG. 53.—Outline map of the north-eastern United States, showing the distribution of Gipsy wheat in 1919. Estimated area, 122,500 acres.

Synonyms.—Defiance, Egyptian, Farmers Friend, Golden Straw, Grains o'Gold, Gipsy Queen, Lebanon, Niagara, and Reliable.

Defiance is the name under which a wheat practically identical with Gipsy was obtained from the Missouri Agricultural Experiment Station in 1913. It is probable that this name became wrongly applied to this wheat, as the writers are not able to find any other record of such application. Egyptian is a name frequently used by farmers for the Gipsy variety. Farmers Friend is the name which has been applied to Gipsy wheat, as well as several other varieties. A sample of Farmers Friend obtained from the Wisconsin station in 1917 as Wisconsin No. 55 proved to be a mixture of Gipsy and Fulcaster. Golden Straw is the name used for a sample of Gipsy wheat obtained from Kansas in 1919. Grains o'Gold is a name applied to a mixed lot of wheat by the J. A. Everitt Seed Co. (O. K. Seed Store), Indianapolis, Ind., and distributed about 1912. They stated it was originated by E. K. Adams, of Allendale, Ill.²¹ Our samples of this wheat contained a considerable proportion of Gipsy with admixtures of Fulcaster, Fultz, and Fultzo-Mediterranean. It was reported in 1919 from Kentucky, Missouri, Ohio, Tennessee, and West Virginia.



FIG. 54.—Outline map of a portion of the central United States, showing the distribution of Valley wheat in 1919. Estimated area, 5,200 acres.

Gipsy Queen is a name used for Gipsy in Indiana. Lebanon is a wheat similar to Gipsy, though it appears to have a slightly harder kernel. Its origin is undetermined. It has been grown by the Ohio Agricultural Experiment Station since about 1893 (204, p. 39). The name Lebanon is used for other varieties of wheat, one of which is identical with Mediterranean and another is very similar to Mammoth Amber. Niagara is the name under which a sample of Gipsy was obtained from Hudsonville, Mich., in 1919. Reliable is a wheat of undetermined origin, practically identical with Gipsy. It was grown by the Ohio Agricultural Experiment Station as early as 1888 (81, p. 29). It was reported in 1919 from Michigan and Pennsylvania.

VALLEY.

Description.—Valley differs from Gipsy only in being taller, slightly earlier, and having slightly longer spikes and glumes. Photographs of a spike, glumes, and kernels of Valley are shown in Plate XXXVII, B.

History.—Valley was obtained by the Ohio station from Elias Tetter, Pleasant Plain, Ohio, in 1883, and grown by them for the first time in 1884 (81, p. 35). It is "said to have originated in the Scioto Valley, Ohio" (114, p. 3).

Distribution.—Grown in Illinois, Indiana, and Ohio, and under synonyms in Kansas and Texas. This distribution is shown in Figure 54.

Synonyms.—German Amber, Indiana Swamp, Niagara, Russian Amber, and Rust Proof.

German Amber is a name used for Valley in Cherokee County, Kans. Indiana Swamp is a name under which a sample of wheat very similar to Valley was obtained from the Illinois station in 1913. A wheat under that name was grown by them as early as 1902. The Everitt O. K. Seed Store advertised Indiana Swamp wheat in 1899, stating that it was of the Mediterranean type. The name Swamp is also used for several other varieties. Indiana Swamp was reported in 1919 from Indiana, Ohio, and West Virginia, but most of the wheat so reported evidently was Mediterranean. Niagara is the name of a wheat obtained from the Missouri Agricultural Experiment Station in 1913, which is

²¹ Correspondence with the Office of Cereal Investigations, dated Sept. 26, 1912.

similar to Valley, except that it has slightly shorter beaks. Its origin is undetermined. A sample of the Niagara variety obtained from Michigan, where the variety was reported, proved to be identical with Gipsy. Niagara is used also as a synonym for Goldcoin in Michigan. Russian Amber is the name under which a sample of wheat was obtained from the Indiana station in 1913. Its previous history is not known. It differs from Valley only in having shorter beaks, as does Niagara. It is not known to be commercially grown. Rust Proof is the name given to a lot of wheat which was obtained in 1919 from Ernest Klappenbach, of Johnson City, Tex., who stated it to be "a rust-resistant strain of wheat developed by continued grading for a series of years." The variety is very similar in many respects to Valley, but is not pure for the straw-color character.

WISCONSIN PEDIGREE NO. 40.

Description.—This variety is similar to Valley except that it is slightly taller.

History.—This is a pure line developed at the Wisconsin Agricultural Experiment Station. The writers obtained their sample in 1917.

Distribution.—Wisconsin Pedigree No. 40 is not known to be commercially grown, as it was not reported in the varietal survey.

SIBLEY (SIBLEY'S NEW GOLDEN).

Description.—Plant winter habit, midseason to late, short to midtall; stem white, slender, weak; spike awned, fusiform, middense, inclined; glumes glabrous, white to yellowish, midlong, narrow; shoulders narrow, oblique to square; beaks 2 to 10 mm. long; awns 3 to 6 cm. long; kernels red, midlong, soft, ovate; germ small; crease narrow, middeep; cheeks rounded; brush small, midlong.

Sibley differs from Gipsy and Valley chiefly in being shorter and later. Other types bearing the name Sibley's New Golden have been observed, one of which has brown glumes and another which has white glumes, purple straw, and large kernels.

History.—"Sibley's New Golden is a light-bearded amber wheat, obtained by crossing the Mediterranean and Clawson" (57, p. 19). It was distributed by the United States Department of Agriculture during the late eighties.

Distribution.—This wheat was formerly cultivated in the Ohio Valley, but now has largely disappeared from cultivation. The variety as above described was reported from Payne County, Okla., in 1919.

FULCASTER.

Description.—Plant winter habit, midseason, midtall; stem purple, strong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide to wide; shoulders midwide, oblique to square; beaks 2 to 8 mm. long; awns 3 to 6 cm. long; kernels red, midlong, soft, ovate, humped; germ mid-sized; crease midwide, middeep, sometimes pitted; cheeks usually angular; brush mid-sized, midlong.

Fulcaster differs from Gipsy and Valley in having purple straw and shorter beaks. A prominent characteristic is the orange-colored stripes on the glumes. It is one of the most popular and widely grown varieties of soft red winter wheat in the United States. A spike, glumes, and kernels of this variety are shown in Plate XXXVIII, A.

History.—According to Carleton (58, p. 70), "Fulcaster was produced in 1886 by S. M. Schindel, of Hagerstown, Md., and is a hybrid between Fultz and Lancaster," the latter being the Mediterranean variety.

Distribution.—Grown as Fulcaster or under one of the many synonyms, in Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, and West Virginia. (Fig. 55.)

Synonyms.—Acme, Acme Bred, Bearded Bluestem, Bearded Purplestraw, Blankenship, Blue Ridge, Bluestem, Canadian, Champion, Corn, Cumberland Valley, Dietz, Dietz Longberry, Dietz Longberry Red, Ebersole, Eversole, Egyptian Amber, Farmers Friend, Georgia Red, Golden Chaff, Golden King, Greening, Improved Acme, Ironclad, Kansas Mortgage Lifter, Kentucky Giant, Lancaster, Lancaster-Fulcaster, Lincoln, Martha Washington, Michigan Red Line, Moore's Prolific, Number 10, Price's Wonder, Red Wonder, Stoner (Eden, Famine, Forty-to-One, Half Bushel, Kentucky Wonder, Marvelous, Millennium,



FIG. 55.—Outline map of the eastern United States, showing the distribution of Fulcaster wheat in 1919. Estimated area, 2,576,500 acres.

Millennium Dawn, Miracle, Multiplier, Multiplying, New Light, New Marvel or Goose, Peck, Russellite, Russell's Wonder, Stooling, Two Peck, Three Peck, Wonderful), Turkish Amber, Tuscan Island, and Winter King.

Acme and Acme Bred were names applied to strains of Fulcaster by S. M. Schindel, seedsman, of Hagerstown, Md., about 1911. The name Improved Acme is now used also for this variety in Maryland. Bearded Bluestem, Bluestem, and Bearded Purplestraw are names used for Fulcaster because the variety has purple stems.

Bearded Purplestraw was first obtained by the Office of Cereal Investigations from Tuscumbia, Ala., in 1899. Blankenship is the name under which a sample of Fulcaster was obtained in 1919 from Stella, Mo., where it had been grown for many years. The report stated that the variety was "very hardy, almost fly proof, branches well, and lays close to ground in winter." Blue Ridge is the name of a wheat practically identical with Fulcaster, which was first obtained from the Kentucky station in 1913. Blue Ridge was reported in 1919 from North Carolina, New Jersey, and Pennsylvania. Canadian is the name under which a sample of Fulcaster was obtained from Dyer, Tenn. It was reported grown in Ohio, Pennsylvania, Tennessee, and Virginia. Champion is the name used for Fulcaster wheat in Genesee County, Michigan. Corn is the name used for a sample of Fulcaster wheat obtained from Cumberland Valley, Pa. Corn wheat, however, usually refers to Polish wheat. Cumberland Valley is a local name used for Fulcaster in Clinton County, Ohio, during the past 10 years.

Dietz, Dietz Longberry, and Dietz Longberry Red are apparently the same variety and morphologically identical with Fulcaster.

Dietz Longberry is reported to have been originated by George A. Dietz, of Chambersburg, Pa. (80, p. 17).



FULCASTER (A).

GOLDEN CROSS (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



CHAMPLAIN (A).

JAVA (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

The earliest record of this wheat is simply under the name "Dietz." It was first included in the varietal experiments of the Ohio station in 1884. The same wheat, however, apparently soon came to be called Dietz Longberry (22, p. 591), and was later known as Dietz Longberry Red (57, p. 18). The true origin of Dietz Longberry and Fulcaster is somewhat obscure. The former has the earlier published history. However, according to N. Schmitz, formerly of the Maryland Agricultural Experiment Station, Mr. Schindel claimed that Mr. Dietz merely gave the name Dietz Longberry to his Fulcaster wheat. Dietz or Dietz Longberry was reported in 1919 from Delaware, Illinois, Indiana, Kentucky, Maryland, New Jersey, New York, North Carolina, Pennsylvania, Tennessee, and Virginia. Some of the wheat reported as Dietz evidently was Mediterranean, as the name Dietz-Mediterranean is a synonym for that variety.

Ebersole and Eversole are names used for Fulcaster in Pennsylvania and Tennessee. Egyptian Amber is the name of a wheat very similar to Fulcaster obtained by the Department from the Indiana station through the Cornell University station in 1912. It was reported in 1919 from Indiana. Farmers Friend is the name used for Fulcaster in Montgomery County, Kans. This name also is used for other varieties. Georgia Red is the name under which Fulcaster wheat has been distributed by H. G. Hastings & Co., seedsmen, of Atlanta, Ga. The name Georgia Red is used in the South also for the awnless wheat Purple-straw. Golden Chaff is the name under which a sample of Fulcaster was obtained from Bethelridge, Ky. Golden King is the name under which a sample of Fulcaster was obtained from Pennsylvania. Greening is a local name used for Fulcaster in Michigan. Ironclad is a name sometimes applied to Fulcaster, although it is most commonly used as a synonym for the Gipsy or Turkey varieties.

Kentucky Giant is a local name for Fulcaster in Illinois. Lancaster is a name often wrongly applied to Fulcaster wheat. It was reported in 1919 from 14 States, but only occasionally under the same description as Fulcaster. Lancaster-Fulcaster is a name of Pennsylvania origin applied by A. H. Hoffman, seedsman, of Landisville, Pa., to Fulcaster wheat grown in Lancaster County, Pa. All the samples of wheat obtained under this name have been Fulcaster. Lincoln is a name used for Fulcaster wheat in Tennessee. Martha Washington is a local name for Fulcaster in Michigan. Michigan Red Line is the name under which a sample of Fulcaster was obtained from Golden City, Mo. Moore's Prolific is the name under which the Fulcaster wheat was obtained from Athens, Tenn. Number 10 is a name used for Fulcaster in Kentucky. Price's Wonder is the name of a wheat identical with Fulcaster, which was distributed for the first time in 1913 by A. H. Hoffman, seedsman, of Landisville, Pa., who gives its origin as follows (177, p. 10, 1916):

Price's Wonder was originated by Prof. R. H. Price, of Virginia, who worked with it five years, during which it yielded one-third more wheat than other kinds of wheat growing near it under like conditions.

Price's Wonder was reported in 1919 from New Jersey, New York, and Pennsylvania. Red Wonder is the name under which Fulcaster wheat has been distributed by T. W. Wood & Sons, seedsmen, of Richmond, Va., since about 1903. The name, however, was recorded for a wheat of unknown character as early as 1892 (177). Red Wonder was reported in 1919 from Connecticut, Iowa, Kentucky, Maryland, North Carolina, Oklahoma, Tennessee, Texas, Virginia, and West Virginia, and doubtless is grown in other States.

Stoner can not be distinguished from Fulcaster by any character and is here considered merely a strain of that variety. The history of Stoner has been recorded by Ball and Leighty as follows (44, p. 15):

Stoner originated on the farm of Mr. K. B. Stoner, of Fincastle, near Roanoke, Va. It was first brought to the attention of the United States Department of Agriculture through a letter from Mr. Stoner, dated June 8, 1906. In the spring of 1904 Mr. Stoner noticed a large bunch of grass in his garden; when headed it proved to be wheat. It had 142 stems, or tillers, and he became impressed with the idea that it was a very wonderful wheat. Just how the kernel of wheat became sown in the garden or from just what variety it came Mr. Stoner does not know. The Fulcaster variety is commonly grown in that section of Virginia, however, and the Bearded Purplestraw less commonly. It is reasonable to suppose, therefore, that the Stoner wheat is a pure line from one of these varieties, which it so closely resembles.

Mr. Stoner increased his seed during the two years, 1905 and 1906, and distributed it in 1907, usually under the name "Miracle." Many extravagant claims were made for it by Mr. Stoner and agents who handled the seed. Because of these claims it afterwards became known under many other names. During 1911 and 1912 the variety was advertised and sold at \$1 a pound by the Watch Tower Bible and Tract Society of Brooklyn, N. Y., under the leadership of "Pastor" Russell. The names Eden, Famine, Millennium, Millennium Dawn, New Light, Russellite, and Russell's Wonder are the result of the advertising and distribution by "Pastor" Russell, who claimed the wheat to be a creation in fulfillment of Biblical prophecy which would replenish the earth. The name Eden was used to imply that the wheat came from the Garden of Eden. Forty-to-One is the name which became applied to Stoner wheat, with the inference that that was the ratio of its increase from the seed sown. The names Half Bushel, Multiplier, Multiplying, Peck, Stooling, Two Peck, and Three Peck became widely applied to the Stoner variety on account of the claims made by Mr. Stoner that the wheat had such remarkable tillering or stooling powers that only a small quantity of seed was necessary to sow an acre. Kentucky Wonder is a name used for Stoner in Indiana. Marvelous is a name which was used for Stoner wheat by J. A. Everitt (O. K. Seed Co.), Indianapolis, Ind., in 1908 and later. The wheat was widely distributed under that name. Miracle, as shown above, is the name under which K. B. Stoner, of Fincastle, Va., first distributed his variety. It was under this name that some very extravagant claims were made for it, which accounts in part for the number of names which since have been applied to it. New Marvel or Goose are names under which the variety was obtained in the vicinity of Salem, Oreg. Wonderful is a name used for Stoner in Kansas.

Stoner, or the names recorded after it in parentheses, was reported in 1919 from Alabama, Arkansas, Delaware, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

Turkish Amber is the name of a wheat similar to Fulcaster, samples of which have been obtained from the Pennsylvania Agricultural Experiment Station. The name appears to have come into use about 1912. Winter King is the name used for a sample of Fulcaster obtained from Table Rock, Pa. This name is applied also to the Goldcoin and Poole varieties.

MAMMOTH RED.

Description.—Mammoth Red is practically identical with Fulcaster, except for being slightly later and shorter and in having a slightly larger and harder kernel.

History.—This variety was first obtained by the United States Department of Agriculture in 1904 from the 101 Ranch, Bliss, Okla. The wheat was distributed by the David Hardie Seed Co., Dallas, Tex., in the early nineties. In experiments at the Maryland Agricultural College, College Park, Md., it is the highest yielding of the many varieties tested at that point, and has been distributed from that station and from Arlington Experimental Farm, Va.

Distribution.—Grown in Indiana, Maryland, Michigan, Missouri, and Virginia.

DIAMOND GRIT.

Description.—Plant winter habit, midseason, short to midtall; stem purple, midstrong, coarse; spike awned, oblong to clavate, middense, inclined; glumes glabrous, white, short, midwide to wide; shoulders midwide, oblique to square; beaks 2 to 15 mm. long; awns 3 to 6 cm. long; kernels red, short to midlong, soft to semihard, usually oval, humped; germ midsized; crease midwide to wide, middeep; cheeks angular; brush midsized, midlong.

This variety is distinguished by its clavate spike and short, oval, semihard kernels.

History.—As recorded by Carleton (58, p. 72), "Diamond Grit is a direct cross of Jones Winter Fife and Early Genesee Giant, and is a bearded, white chaffed, semihard, red-grained variety."

The cross was made by A. N. Jones, of Newark, Wayne County, N. Y. On Mr. Jones's stationery it is listed as a variety of wheat which he originated in 1896.

The variety was advertised and distributed by Peter Henderson & Co., seedsmen, of New York City, in 1897.

Distribution.—This wheat is not known to be grown commercially at the present time. It is still included in experiments, however, at several stations in the eastern United States.

Synonym.—Winter Saskatchewan. This name has been used as a synonym for Diamond Grit in advertisements of the variety.

GOLDEN CROSS.

Description.—This variety is similar to Diamond Grit except in having a shorter culm, shorter, more erect and more clavate spike, and a larger kernel. A spike, glumes, and kernels of Golden Cross are shown in Plate XXXVIII, B.

History.—This wheat was originated by A. N. Jones, of Newark, N. Y., in 1886. According to Mr. Jones's stationery, it was the first wheat which he produced. Peter Henderson & Co. (110) advertised and distributed this variety in 1888, claiming it to be a cross between Mediterranean and Clawson. The sample grown by the writers was obtained from the farm of Max Berg, near Beaverton, Washington County, Oreg., in the summer of 1916.

Distribution.—Reported in 1919 from Kentucky, Michigan, and Ohio. It probably still is grown in Oregon also. Other varieties of wheat sometimes are called Golden Cross.

CHAMPLAIN (PRINGLE'S CHAMPLAIN).

Description.—Plant spring habit, midseason, tall; stem white, strong; spike awned, fusiform, middense, erect; glumes glabrous, yellowish white, midlong to long, midwide; shoulders narrow to midwide, oblique to square; beaks 1 to 5 mm. long; awns, 2 to 7 cm. long; kernels red, short to midlong, usually semihard, ovate; germ midsized; crease midwide, middeep; cheeks angular; brush midsized, midlong to long, collared.

This variety is distinct in having short, wide, semihard red kernels with a long, collared brush. The lower leaves of Champlain are distinctly pubescent. A spike, glumes, and kernels of Champlain wheat are shown in Plate XXXIX, A.

History.—The following history of Champlain was published in the Rural New Yorker in 1877 (13):

Champlain was produced in 1870 by Mr. Pringle in his endeavors to unite the hardness of the Black Sea with the fine qualities of the Golden Drop. Several varieties were the result of this cross, from which the above was chosen as showing increased vigor and productiveness over its parents. A selection from this for the past seven years has now, Mr. Pringle thinks, established its character, and the result is a wheat bearded like the Black Sea with the white chaff of the Golden Drop.

C. G. Pringle did his wheat breeding at Charlotte, Vt., near Lake Champlain. This wheat evidently was named for the lake.

Pringle's Champlain is the name under which the variety first became known. Mr. Pringle apparently, however, did not intend that his name should be a part of the name of any of the varieties of wheat which he distributed.

Distribution.—Grown as Pringle's Champion, chiefly under irrigation, in Yellowstone County, Mont., and Park County, Wyo.

Synonym.—Pringle's Champion. This name is wrongly but most commonly used by growers of the Champlain variety.

JAVA (EARLY JAVA).

Description.—Plant spring habit, early, midtall; stem white, slender, mid-strong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong to long, narrow to midwide, easily deciduous; shoulders wanting to narrow, oblique; beaks 2 to 15 mm. long; awns, 2 to 8 cm. long; kernels red, midlong, soft, ovate to elliptical, pointed; germ small to midsized; crease midwide, middeep; cheeks usually angular; brush midsized, midlong, slightly collared.

The above is the description of the most common type of Java, which usually is distinguished by its long beaks. There are many types in the Java variety as grown in the field, including both hard and soft kernels, white and brown glumes, and various lengths of beaks. Plate XXXIX, B, shows a spike, glumes, and kernels of Java wheat.

History.—This variety is probably one of the oldest spring varieties grown in the United States. It apparently was first known as Siberian, concerning which the following was recorded in 1837 (1):

"Cultivator" says: Received sample from Dr. Goodsell, of Utica, said to have come from Switzerland. Prolific, heavy yielder of grain (40 bushels) and of flour.

A Siberian variety was also reported from Farmville, Va., in 1849 (145, p. 132):

Wheat.—The favorite varieties of this grain are, first, The Turkey, called also Siberian wheat. A small parcel of this was brought from South Carolina by the late Rev. James Wharey and divided between the late Captain Pemberton and myself. This variety is excellent, weighing remarkably and making superior flour. It is now nearly lost in this neighborhood from admixture and other causes of deterioration.

China Tea, sometimes referred to as Black Tea, wheat is also identical with Java and has the following history, as reported by Klippart (131, p. 758):

Some 12 years since (1845) there was found by a merchant in Petersburg, Rensselaer County, N. Y., six or seven kernels of this kind of wheat, in a chest of black tea, which was sown. It now has the preference of all the different varieties of spring wheat. The straw is very stiff and has never been known to

rust. It thrashes very easily. It should be cut rather early, as it is liable to shell if left till fully ripe. The quality of the flour is equal to any other spring wheat. It is said to yield from 15 to 40 bushels per acre.

China Tea wheat was listed in 1863, in a report of the standing committee of the Iowa Agricultural Society, as the first spring-wheat variety preferred by growers (4, p. 518). This fact, together with the identity of the samples grown by the writers and the importance of Java in Iowa, indicates that Java is simply a new name for the China Tea variety. China Tea was reported from New York in 1919.

In 1899 Wallaces' Farmer, of Des Moines, Iowa, published several short articles on the desirability of growing early varieties of wheat and oats. A request was made to their readers to report any variety of spring wheat that was grown which would ripen in Iowa by the Fourth of July. Among several of the varieties that were reported was the Early Java, from C. F. Morton, southeastern Nebraska (26). As a result of this request, Early Java wheat was grown in 1900 at the Iowa Agricultural Experiment Station, Ames, Iowa, and on the farm of M. E. Ashby, living 5 miles north of Des Moines. For several years Wallaces' Farmer entered into an active campaign for the distribution of Early Java wheat. The variety thus became quite widely grown in that State. In a recent issue of Wallaces' Farmer the following reference concerning the origin of the variety is given (33):

About 20 years ago a southeastern Nebraska farmer was growing an early variety of spring wheat under the name of Early Iowa or Early Java. He wrote to Henry Wallace, of Wallaces' Farmer, about it in 1899, and as a result Mr. Wallace wrote about it considerably in the paper and induced a number of Iowa farmers to try it out. In a short time the Early Java became the most popular spring wheat in Iowa. No one knew where it came from originally. . . .

Early Java may be a misspelling of "Early Iowa," the German spelling of Early Iowa, given above as a synonym. This possibly is an explanation of the origin of the name Early Java.

Distribution.—Grown in Illinois, Iowa, Nebraska, and Wisconsin, and as China Tea in New York. (Fig. 56.)

Synonyms.—Black Tea, China Tea, Early Iowa, Siberian, Swedish, and Tea Leaf. Swedish is a name under which samples of Java have been received from Nebraska. It is evidently a local name for Java wheat in that State. Tea Leaf was reported for Java from Iowa. The other synonyms listed above have been mentioned in the history of Java.

ERIVAN.

Description.—Plant spring habit, early, short; stem white, slender, very weak; spike awned, fusiform, middense, nodding; glumes glabrous, white, midlong, narrow; shoulders midwide, usually elevated; beaks 3 to 25 mm. long; awns 2 to 7 cm. long; kernels red, midlong, soft, elliptical, humped; germ small; crease midwide, shallow; cheeks usually angular; brush small, midlong.

Erivan differs from Java chiefly in having an elevated shoulder on the glume.

History.—The Erivan variety (S. P. I. No. 9871) was introduced by the United States Department of Agriculture (197) in 1903, from the dry mountain district of the Erivan Government in Transcaucasian Russia, near the border of Persia.

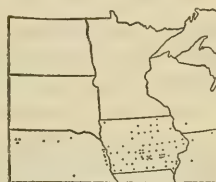


FIG. 56.—Outline map of the north-central United States, showing the distribution of Java wheat in 1919. Estimated area, 55,000 acres.

Distribution.—Grown to a limited extent in Wyoming. It has been grown in experiments in the northern Great Plains area and has proved to be a high-yielding, drought-resisting wheat. Its weak stem has prevented it from being of commercial importance.

CONVERSE.

Description.—Plant spring habit, midseason, tall; stem white, midstrong; spike awned, fusiform, middense, inclined to nodding; glumes glabrous, white, midlong, narrow; shoulders wanting to narrow, oblique; beaks 3 to 20 mm. long; awns 3 to 8 cm. long; kernels pale red, midlong, soft to semihard, ovate, humped, acute at base; germ mid-sized, abrupt; crease midwide, middeep; cheek usually angular; brush mid-sized, short to midlong.

Converse differs from Erivan in being taller and later and in having a harder kernel.

History.—The origin of Converse is undetermined. The sample here described was obtained in 1908, and the wheat had doubtless been grown for several years previous under the name Red Russian. The variety was renamed in 1920 (66, p. 6) and the following information recorded:

The name Converse is here given to a commercial variety of spring wheat grown in Wyoming under the name Red Russian. The name Red Russian is used for three other varieties in the United States, so a new name has been selected for this variety. The original sample (C. I. No. 4141) was obtained by a representative of the Department of Agriculture from Converse County, Wyo., hence the name.

Distribution.—Grown in Nebraska and Wyoming.

Synonym.—Red Russian is the local name under which this wheat has been grown for several years in the State of Wyoming.

MINTURKI.

Description.—Plant winter habit, midseason, midtall; stem white, weak; spike awned, fusiform, middense, inclined; glumes glabrous, yellowish white, midlong, narrow; shoulders wanting to narrow, oblique; beaks 1 to 3 mm. long; awns 4 to 8 cm. long; kernels red, midlong, semihard, ovate to elliptical, acute; germ small; crease narrow, shallow to middeep; cheeks rounded; brush small, midlong to long.

This variety is very winter hardy. It resembles Turkey except in having softer kernels and in being more winter hardy.

History.—This variety is the progeny of a cross between Odessa and Turkey, made at the Minnesota Agricultural Experiment Station, University Farm, St. Paul, in 1902, during the time Prof. W. M. Hays was in charge of plant breeding there. Odessa was used as the female parent and Turkey as the male parent. Of the many selections made from the progeny of this cross two have shown sufficient value to be named and distributed by the Minnesota station. This selection was first known as Minnesota No. 1507, but was named Minturki in 1919 (106, p. 17-28) when it was first distributed.

Distribution.—Grown to a slight extent in Minnesota and by experiment stations in other Northern and Western States.

Synonym.—Minnesota No. 1507.

HUSSAR (RED HUSSAR).

Description.—Plant winter habit, late, midtall; stem white, slender, weak to midstrong; spike awned, fusiform, middense to lax, inclined to nodding; glumes glabrous, white, long, midwide, easily deciduous; shoulders midwide,

oblique to square; beaks 1 to 3 mm. long; awns 3 to 8 cm. long; kernels red, midlong, semihard, ovate, humped; germ midsized; crease midwide, shallow to middeep, pitted; cheeks usually rounded; brush midsized, long.

This variety is similar to Turkey, but has softer and more humped kernels. The strain described above, which is a pure line from the original Red Hussar, apparently is immune to bunt (stinking smut).

History.—The origin of Hussar (Red Hussar) is undetermined. It was grown by the Illinois Agricultural Experiment Station, Urbana, Ill., for the first time in 1906 (122, p. 73) and is still grown by that station. The variety was obtained by the United States Department of Agriculture from the above source in 1913.

Distribution.—Hussar is not known to be grown commercially, but is grown by several experiment stations in the United States.

PESTERBODEN.

Description.—This variety is nearly identical with Turkey, except in being slightly taller and in having somewhat larger and softer kernels. Some of the varieties listed below as synonyms contain strains which can not be distinguished from Turkey.

History.—This variety was first introduced into the United States by the United States Department of Agriculture in 1900 from Budapest, Austria-Hungary.

Distribution.—This variety and those synonymous were not reported grown in 1919. The wheat has been grown by many experiment stations and was distributed to some extent in former years. The writers have been informed that Pesterboden is being grown in Wisconsin.

Synonyms.—Budapest, Hungarian, Torgova, and Weissenburg.

Budapest was first introduced into the United States in 1892 from Budapest, Hungary, by C. G. A. Voigt, a miller of Grand Rapids, Mich. (75, p. 142). Several other introductions under the name of Budapest have been made, most of which were practically identical with Turkey. Some strains, however, are slightly taller, with a somewhat softer kernel.

Hungarian is the name under which many introductions of hard red winter wheat have been made. Most of these strains were identical with Turkey, as were almost all of the introductions from Hungary. However, some strains are slightly taller and have somewhat softer kernels than typical Turkey wheat. Some of the earlier samples obtained by the department under this name were from the Argentine exhibit at the Louisiana Purchase Exposition, in 1904. Torgova was introduced by M. A. Carleton, of the United States Department of Agriculture, in 1900. The original sample was grown near Torgova, an extreme northern portion of the Stavropol Government on the Tsaritsyn Branch of the Vladikarkaz Railway. It was obtained from the Turkin Flour Milling Co., at Tsaritsyn (S. P. I. No. 6007). Weissenberg was introduced into the United States from Budapest, Austria-Hungary, in 1900 by the United States Department of Agriculture (197, S. P. I. No. 5499).

BLACKHULL (CLARK'S BLACK HULLED).

Description.—Plant winter habit, early to midseason, midtall to tall; stem white, fine, midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, with black stripes, midlong, midwide; shoulders wanting to narrow, oblique; beaks 1 to 3 mm. long; awns 2 to 7 cm. long; kernels red, midlong, semihard to hard, usually elliptical; germ small; crease narrow, shallow; cheeks rounded; brush midsized, midlong.

This variety is a few days earlier than Turkey and has a softer kernel. Except under certain unfavorable weather conditions, the glumes of Blackhull have black stripes on the surface or sometimes are almost entirely black.

History.—This variety was originated by Earl G. Clark (63), of Sedgwick, Kans., as a selection from a field of Turkey. He states:

The Clark's Black Hull wheat is a wonderful hardy variety of wheat that I have developed from three black heads found in 1912. It has proven superior to all other varieties of winter wheat.

The variety was first distributed by Mr. Clark in the fall of 1917.

Distribution.—Grown in Harvey County, Kans.

Synonym.—Black Chaff. This name is occasionally used for the Blackhull variety.

TURKEY (TURKEY RED).

Description.—Plant winter habit, midseason, midtall; stem white, slender, weak; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders wanting to narrow, oblique; beaks 2 to 8 mm. long; awns 3 to 8 cm. long; kernels dark red, midlong, hard, ovate to elliptical; germ small; crease narrow to midwide, middeep; cheeks rounded; brush small, midlong.

This variety is winter hardy and drought resistant, which accounts for its wide cultivation. The first leaves of the stool are narrow and of a dark-green color. The kernels are usually distinguishable because of their dark-red color and small germ. A spike, glumes, and kernels of Turkey wheat are shown in Plate XL, A, and a single spike in Plate IV, Figure 5.

History.—Turkey is the name most commonly used for the Crimean group of hard winter wheats grown in the United States. Many histories of this wheat have been written. That recorded by Carleton (60, p. 298-399) is given here, however, as he introduced many strains and spent much time in an attempt to determine accurately the history of the wheat.

The original home of hard winter wheat is in the area of Russia just north and east of the Black Sea and north of the Caucasus Mountains. The area includes chiefly the governments of Taurida (including the Crimea), Ekaterinoslav, Kharkof, and Stavropol, and the Don and Kuban territories. In that region the wheat is generally called simply winter wheat, but is known locally by various names as Krimka (Crimean), Kharkof, Beloglina, Ulta, Torgova, etc. . . .

The history of hard winter wheat in the United States is closely associated with the movement of Russian Mennonite immigrants to the middle Great Plains. These people originally went from west Prussia to southern Russia about 1770 because of certain land grants and civil privileges offered by the Government under Empress Catherine. One hundred years later their descendants desiring further advantages to be obtained in America emigrated to the middle Great Plains and settled principally in Kansas. The greater number were from the Molochna colonies in northern Taurida, but some were from the Crimea proper, and others from Ekaterinoslav. The first settlements in Kansas were made in 1873, near Newton, Halstead, and Moundridge. Each family brought over a bushel or more of Crimean wheat for seed, and from this seed was grown the first crop of Kansas hard winter wheat. Bernard Warkentin, a miller, who erected mills at Newton and Halstead, was chiefly instrumental in introducing the Turkey wheat, but in this pioneer movement of the Mennonites two other men were associated, Christian Krehbiel, first a farmer, but who later in 1886 erected a mill at Moundridge, and C. B. Schmidt, acting as immigration agent for the Santa Fe Railroad.

Distribution.—Grown in Alabama, Arizona, Arkansas, California, Colorado, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Mexico, New York, North Dakota,



TURKEY (A).

KANRED (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



PRESTON (A).

KOTA (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, Wyoming. This distribution is shown in Figure 57.

Synonyms.—Alberta Red, Argentine, Bulgarian, Crimean, Defiance, Egyptian, Hard Winter, Hundred-and-One, Hungarian, Improved Turkey, Kharkof, Lost Freight, Malcome, Malakof, Minnesota Red Cross, Minnesota Reliable, Pioneer Turkey, Red Russian, Red Winter, Romanella, Russian, Tauranian, Theiss, Turkey Red, Turkish Red, Ulta, Wisconsin No. 18, Worlds Champion.

Alberta Red is a name which was originally given a lot of Turkey wheat grown about 20 miles from Calgary, Alberta, Canada, in 1906. Selections of heads of the variety were made under the direction of W. M. Gilfoy, manager of the Calgary Milling Co. An extra good sample was thus obtained, which

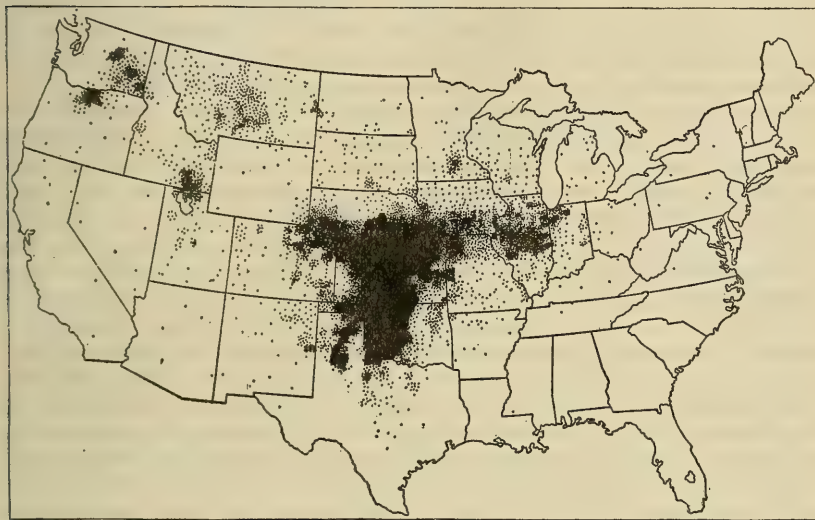


FIG. 57.—Outline map of the United States, showing the distribution of Turkey wheat in 1919. Estimated area, 21,588,300 acres.

was distributed under the name Alberta Red. Argentine is a name under which a strain of Turkey wheat has been grown at the Sherman County branch station, Moro, Oreg., for a number of years. In the experiments there it has proved to be one of the highest yielding strains of Crimean wheat. The wheat was obtained on the stock exchange, Marseilles, France, in 1900, by W. T. Swingle, of the Department of Agriculture (197, S. P. I. No. 5354). It is recorded as being one of a collection of different types of macaroni wheat, but this particular lot proved to be common wheat of the Turkey type. Bulgarian is a name under which a sample of Turkey wheat was obtained from the Indiana Agricultural Experiment Station in 1913.

Crimean is the name properly used for this whole group of hard red winter wheats. It also has been used as a varietal name for separate introductions. The first introduction of the wheat under this name is thought to have been made by Carleton in 1900 (197, S. P. I. No. 5635) from Kurman-Kemelchi, Central Crimea, Russia. Defiance is a name under which a lot of Turkey wheat was distributed by the Iowa Seed Co., of Des Moines, Iowa. It was advertised as their novelty of 1900, which was the first year the name was applied to a hard red winter wheat. Egyptian is a name sometimes used for Turkey, as well as other varieties. A sample of Turkey under this name was obtained

from Dumbell, Wyo., in 1919. In a letter dated July 8, 1919, accompanying the above sample, C. A. Smith states: "This wheat was brought direct from Egypt by a missionary and is the same wheat my father used to grow in Michigan." Egyptian was reported in 1919 from Indiana, Michigan, Missouri, Ohio, Wyoming, and Wisconsin. A part of this, however, is believed to be other varieties, such as Gipsy and Egyptian Amber (Fulcaster).

Hard Winter is a name commonly used for Turkey wheat, but is properly used only as a class or grade name for this type of wheat. Hundred-and-One, or 101, is a name used for Turkey wheat distributed by the 101 Ranch, of Bliss, Okla. The variety is grown under this name to some extent in Kansas, Missouri, Oklahoma, and Texas. Hungarian is the name used for some samples of Turkey wheat, but also for types identical with Pesterboden. The Hungarian wheat is more fully discussed along with the Pesterboden variety. Improved Turkey is a selected strain of Turkey developed at the Kansas station and is also known as P-706. It has been used in cooperative experiments conducted by that station with farmers, but otherwise is not grown commercially.

Kharkof, for the most part, is a wheat morphologically identical with Turkey. Several introductions were made which came from a region much farther north, and it was, therefore, thought to be a much more winter hardy wheat than Turkey. The Kharkof wheat was first introduced into the United States by M. A. Carleton in 1900, from Starobelsk, Kharkof, Russia (197, S. P. I. No. 5641; C. I. No. 1442). Two other strains (S. P. I. No. 7467, C. I. No. 1583; and S. P. I. No. 7786, C. I. No. 2193, or C. I. No. 6206), were obtained in 1901 through Dr. A. Boenicke, president of the Kharkof Agricultural Society. The latter of these two introductions contain a considerable portion of long-beaked strains more similar to Beloglina than the true Kharkof. A fourth lot of Kharkof (S. P. I. No. 9125, C. I. No. 2208), consisting of 450 bushels, was received in 1902 from the Starobelsk district through Mr. E. A. Bessey. For several years these strains of Kharkof wheat gave slightly better results than the ordinary Turkey wheat of Kansas and became quite widely distributed in that State, as well as in Wyoming and Montana. In recent years, however, little difference in hardiness or yield has been observed, except in northern Wyoming and in Montana, where it still consistently yields better than Turkey.

Lost Freight is a name used for the Turkey or Hundred-and-One variety in Missouri. Malcome is the name under which a sample of Turkey was obtained from Harford City, Ind., in 1919. This is probably only a confusion of the name Malakof.

Malakof is a name under which many strains of Crimean wheat have been introduced and grown. It is thought to have been first distributed by the Ratekin Seed Co., Shenandoah, Iowa, in the early nineties from seed which was said to have come from Russia. Malakof was reported from Illinois, Indiana, Kansas, Michigan, Missouri, and Oklahoma. Minnesota Red Cross is the name under which a sample of wheat similar to Turkey was obtained by the department from the Oklahoma Agricultural Experiment Station in 1917. Minnesota Reliable is the name under which a sample of wheat similar to Turkey was obtained from the Illinois Agricultural Experiment Station in 1917.

Pioneer Turkey is a name used for Turkey by P. J. Jennings, of McCracken, Kans. About 1910 he obtained an old sample of Turkey wheat from an elevator man in Topeka, who believed it to be from the earliest Turkey wheat grown in Kansas. Concerning this, Mr. Jennings has written:²²

²² Correspondence with A. F. Swanson, Hays Experiment Station, Hays, Kans., dated September 12, 1920.

We kept selecting and planting same with every care until at last our whole farm was producing this strain and as pure as it was possible to be had, and to-day it has under this treatment almost developed an individuality all its own. Knowing its relation to other days and as we had given it so much care and attention without any aid or encouragement from any one and had in the meantime lost track of the man who had helped us get the first seed, we decided, for the want of a better name, to call the wheat "Pioneer Turkey," in honor of its early history and, too, because our farm on which all this work was done was known as "Pioneer Place."

Red Russian is a name commonly used by farmers for Turkey wheat in Kansas and other hard winter-wheat-producing States. Red Winter, like Red Russian, is a name commonly used for Turkey wheat by farmers. It has also been used as a varietal name for several strains of Turkey wheat grown by experiment stations. Romanella is a name under which a sample of wheat similar to Turkey was obtained by the Department of Agriculture from Haage & Schmidt, Erfurt, Germany, in 1904. Russian is a name commonly used for Turkey wheat by Kansas farmers. Tauranian is the name recently applied to a sample of wheat practically identical with Turkey which was obtained by G. W. Ripka, Salina, Kans., from an agricultural college in the Province of Taurida, Russia, in the spring of 1914. Some strains of this wheat have long beaks and are apparently identical with Beloglina. This wheat has been grown at the Kansas Agricultural Experiment Station since 1916. Mr. Ripka has grown about 1,000 acres of it annually since 1914, and has distributed the seed quite generally in his neighborhood. Theiss is the name of an introduction of Turkey wheat from Budapest, Austria-Hungary, made in 1900 by the United States Department of Agriculture. Earlier introductions of Theiss have been grown in the eastern part of the United States.

Turkey Red is the name first used for Turkey wheat throughout Kansas in the early seventies. During the last decade, however, the word Red generally has been omitted. Turkish Red is a name long used for Turkey wheat in Iowa. This is the name under which the wheat was distributed in 1886 by George W. Franklin, of Atlantic, Iowa, who is reported to have been the first man to distribute this wheat in that State (54, p. 263).

Ulta wheat, which is identical with Turkey, was first introduced into the United States from Constantinovskol, 40 miles east of Stavropol, in north Caucasus, in 1900 by M. A. Carleton, of the United States Department of Agriculture (197, S. P. I. No. 5638). Wisconsin No. 18 is a lot of Turkey wheat distributed quite widely in Wisconsin by the Wisconsin Agricultural Experiment Station. Worlds Champion is a name under which a sample of Turkey was obtained from the Illinois Agricultural Experiment Station in 1917.

IOWA NO. 404.

Description.—Iowa No. 404 is identical with Turkey morphologically, but in experiments in Iowa it has shown greater winter hardiness and proved more productive.

History.—It is a pure-line selection of Turkey (Minn. No. 529) developed at the Iowa Agricultural Experiment Station and first distributed by them in the fall of 1913 as a winter-hardy and high-yielding pure strain of Turkey wheat.

Distribution.—Grown in Illinois, Iowa, and Wisconsin.

IOWA NO. 1946.

Description.—This is another pure line similar to Turkey, but superior to it in yield and winter hardiness.

History.—Iowa No. 1946 is a more recent and apparently superior selection developed at the Iowa Agricultural Experiment Station. It is a pure line from a mixed strain of wheat known as Iowa No. 1661, which was supposed to have been selected from Banat. The latter was introduced from Russia, but was originally from the Banat district in Hungary.

Distribution.—Grown to a small extent in Iowa in 1921.

MONTANA NO. 36.

Description.—This variety can not be distinguished from Turkey, but has proved superior to it in winter hardiness and yield in experiments and commercial trials in Montana.

History.—It is a pure-line selection of Kharkof developed at the Montana Agricultural Experiment Station, Bozeman, Mont., and distributed by them since the fall of 1915 as a winter-hardy, high-yielding strain.

Distribution.—Grown in Montana.

NEBRASKA NO. 60.

Description.—Nebraska No. 60 is practically identical with Turkey in all taxonomic characters.

History.—This is a high-yielding pure-line selection of Turkey wheat developed at the Nebraska Agricultural Experiment Station. It was distributed for commercial growing and for testing at experiment stations in other States in the fall of 1918. Another selection, Nebraska No. 6, was distributed at the same time.

Distribution.—Grown in Nebraska.

WISCONSIN PEDIGREE NO. 2.

Description.—This variety is identical with Turkey.

History.—Wisconsin Pedigree No. 2 is a pure-line selection of Turkey wheat developed by the Wisconsin Agricultural Experiment Station and distributed by them as a high-yielding strain since the fall of 1918.

Distribution.—Grown in Wisconsin.

KANRED.

Description.—Plant winter habit, midseason, midtall; stem white, weak; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders narrow, oblique to elevated; beaks 3 to 25 mm. long; awns 3 to 10 cm. long; kernels dark red, midlong, hard, ovate, to elliptical; germ small; crease narrow to midwide, middeep; cheeks rounded; brush small, midlong.

Kanred is very similar to Turkey, but is slightly more winter hardy and slightly earlier and can be distinguished from that variety by its longer beaks on the outer glumes and by its resistance to some forms of both leaf and stem rust. This resistance to rust is an important factor in the ability of the variety to outyield Turkey wheat in many sections. It is also about equal to Turkey in milling and bread-making value. A spike, glumes, and kernels of Kanred are shown in Plate XL, B.

History.—Kanred is the product of a single head selected in 1906 from the Crimean variety (C. I. No. 1435), which had been introduced into the United States from Russia by the United States Department of Agriculture. The selection from which it descended was one of 554 head selections made in 1906 by Dr. H. F. Roberts, of the Botany Department of the Kansas Agricultural Experiment Station (162). In 1911 the more promising strains were included

in experiments by the Agronomy Department of the Kansas station, and several of them, including Kanred, were grown in field plats. In 1916 it was discovered to be rust resistant. During these years of preliminary testing of the Kanred wheat it was known by the number P-762. In 1917 it was named Kanred (a contraction of Kansas Red). About 4,000 acres were seeded to this variety in the fall of 1917, more than 50,000 acres in the fall of 1918, and not less than 500,000 acres in the fall of 1919.

Distribution.—Kanred was reported in 1919 from 23 counties in Kansas, 1 county in Michigan, and 5 counties in Oklahoma. (Fig. 58.) Probably 1,500,000 to 2,000,000 acres were sown to Kanred in the fall of 1920. It is grown also at experiment stations in most sections of the United States.

Synonyms.—P-762, P-1066, and P-1068. P-762, as shown above, was the designation under which Kanred wheat was known from the date of its selection, in 1906, until the time when it was named. P-1066 and P-1068 are two other pure-line selections developed at the Kansas Agricultural Experiment Station in much the same way as was Kanred. Both these strains have the rust resistance of Kanred and are identical in all morphological characters, but neither has been distributed for commercial growing.

BELOGLINA.

Description.—This variety is nearly identical with Kanred, except that it is slightly later and does not have the resistance of that variety to stem and leaf rust.

History.—Beloglina was introduced from Russia by the United States Department of Agriculture. Four introductions have been made. The first lot was obtained by M. A. Carleton in 1900 from Rostov on Don, Russia (197, S. P. I. No. 6012), where it was claimed to have been one of the most hardy red winter wheats known. It was grown near Beloglinskaya, in the northern portion of the Stavropol Government, a region of great extremes of temperature and moisture. This wheat has proved somewhat more winter hardy than commercial strains of Turkey and Kharkof, but not enough so to make it become an important variety.

Distribution.—This variety is not known to be grown commercially, but is grown at many experiment stations in the western United States.



FIG. 58.—Outline map of a portion of the central United States, showing the distribution of Kanred wheat in 1919. Estimated area, 97,500 acres.

BACSKA.

Description.—The Bacska wheat grown in Wisconsin is very similar to Kanred, except that it is slightly taller and later and does not have the resistance of Kanred to stem and leaf rust.

History.—The original Bacska wheat (197, S. P. I. No. 5498) was introduced from Budapest, Austria-Hungary, in 1900 by the United States Department of Agriculture. A pure-line selection made from the original introduction by E. J. Delwiche, of the Wisconsin Agricultural Experiment Station at Ashland, Wis., is the only Bacska wheat now known to be commercially grown. It is sometimes called Wisconsin Pedigree No. 408.

Distribution.—This variety was reported in 1919 from Bayfield and Price Counties, Wis., where it made up 17 and 2 per cent of the wheat acreage, respectively.

Synonym.—Wisconsin Pedigree No. 408.

PRESTON (VELVET CHAFF).

Description.—Plant spring habit, midseason, midtall; stem white, sometimes faintly purple, especially on lower internodes, midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide, easily deciduous; shoulders wanting to narrow, oblique; beaks 1 to 3 mm. long; awns 2 to 7 cm. long; kernels red, midlong, hard, ovate; germ mid-sized; crease narrow to midwide, shallow to middeep, triangular; cheeks angular; brush mid-sized, midlong.

The kernels of Preston are distinguished from other hard red wheats by the dull seed coat and the rather narrow triangular crease. A spike, glumes, and kernels of Preston wheat are shown in Plate XLI, A.

History.—The Preston variety was bred from a cross between Ladoga, a Siberian wheat, and Red Fife. The hybrid was made by Dr. William Saunders, at the Central Experimental Farm, Ottawa, Canada, in 1888. It was grown at the experiment station at Indian Head, Saskatchewan, as early as 1893, and was sent to the Minnesota Agricultural Experiment Station for growing in the spring of 1896.

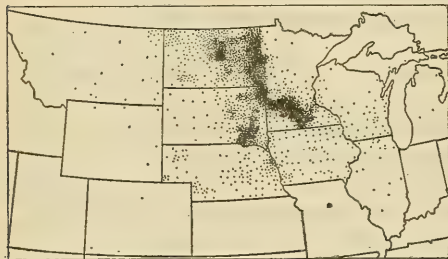


FIG. 59.—Outline map of the northwestern United States, showing the distribution of Preston wheat in 1919. Estimated area, 2,233,200 acres.

It is not known definitely that the "Velvet Chaff" wheat now widely grown is Preston and is the result of the above distribution. It is probable that some of this wheat is an older variety from which the original name had been lost. In addition to the synonyms, listed below, which represent sorts apparently identical with the commercial Velvet Chaff spring wheat, there are types of wheat found

within the Java variety which can not be distinguished from the Velvet Chaff or Preston.

Distribution.—Grown (principally as "Velvet Chaff") in Colorado, Illinois, Iowa, Kansas, Michigan, Minnesota, Montana, Nebraska, North Dakota, South Dakota, Wisconsin, and Wyoming. (Fig. 59.)

Synonyms.—Bearded Fife, Blue Ribbon, Climax, Golden Drop, Johnson, Johnson's Early Fife, Minnesota No. 188, Red Fife, Velvet Chaff.

Bearded Fife is the name chiefly used for the Preston variety in South Dakota since 1904, or earlier, although in more recent years it is commonly called Velvet Chaff. The name Bearded Fife was used to distinguish this wheat, which was also often called Red Fife, from the well-known Red Fife wheat of Canada. Blue Ribbon is the name of a selected lot of a wheat, apparently identical with Preston, distributed by H. E. Krueger, of Beaver Dam, Wis., since about 1909. He stated²³ that the wheat "was selected 10 years ago, from an old fife variety, and ripens about with Marquis." Blue Ribbon is grown in Illinois, Iowa, Michigan, North Dakota, Ohio, and Wisconsin. Climax, sometimes called South Dakota Climax, was first obtained by the South Dakota Agricultural Experiment Station in 1903 from John Carpenter, Hetland, S. Dak. It apparently is the Preston variety and was formerly grown to a considerable extent under the name Climax in South Dakota. Golden Drop is the name under which a sample of wheat identical with Preston was obtained in

²³ Correspondence with the Office of Cereal Investigations, dated Apr. 26, 1917.

Iowa in 1919. A definite history of the bearded spring Golden Drop variety is not available, but this is probably an old English wheat. A spring wheat similar to the above was grown under this name in New Hampshire in 1872 (9, p. 492).

Johnson is a name of a wheat similar to or identical with Preston. A Johnson or No. 55 has been reported by J. M. Thorburn & Co. as "an amber, bearded, white-chaff variety," originated in 1889 by E. S. Carman, then editor of the *Rural New Yorker* (191, p. 48). *Rural New Yorker* No. 55 also was described in 1888 (23, p. 523) as a "pure wheat cross. Medium to ripen. Stems yellow. Heads average nearly 4 inches. Eight breasts to a side. Chaff white, heavily bearded, three to four grains to a breast, fair size, bright amber color, hard regular heads, i. e., not inclined to club." In 1890 the *Rural New Yorker* (24, p. 516) reported "No. 55 has been named 'Johnson' after Prof. S. W. Johnson, of Yale." A Johnson wheat was grown in California as early as 1871 (7).

The Marysville "Appeal" has seen some samples from a field of wheat growing near Yuba City which are reported to be an average of the crop of about 40 acres of the bearded Chile variety and give promise of a good crop without further rain. The proprietor estimates a yield of from 30 to 40 bushels per acre. This variety of wheat is highly prized by the grain growers of Sutter, and is known as the Johnson wheat.

Johnson wheat was reported in 1919 from Iowa, Minnesota, South Dakota, and Wisconsin. Samples of this wheat resemble Java and Dixon as well as Preston. Johnson's Early Fife is a name used for the wheat which later became known as Bearded Red Fife or Red Fife bearded, which is identical with the commercial Velvet Chaff or Preston. Wheeler and Balz (203) state:

The so-called Red Fife, a hard, red, bearded wheat, . . . The origin of this variety, which is also called Golden Fife and Johnson's Early Fife, is somewhat obscure.

It is not certain that this wheat is identical with other lots of Johnson.

Minnesota No. 188 is a number given by the Minnesota Agricultural Experiment Station to Preston wheat which was received from Dr. William Saunders, of Ottawa, Ontario, Canada. The following extract is from the records of the Agronomy Division of the Minnesota station:

Minnesota 188 was originated by Dr. William Saunders, of the Canadian Experimental Farms. It was the result of a cross between Red Fife and Ladoga made in 1889. It was improved by selection by Dr. Saunders and received at Minnesota in 1896. As introduced to farmers in Minnesota it contained both red and white seeds, and it was recalled. It should not be considered as a Minnesota pedigree.

Preston wheat from the above source, frequently designated as Minnesota No. 188, is still grown to a considerable extent in Minnesota. Red Fife is a name under which Preston wheat was grown in South Dakota as early as 1905. Although incorrectly applied, this name continued in use for several years.

Velvet Chaff is a name which came into use about 1905 for a wheat similar to Preston or identical with it. Just how and when this particular name arose is not known. By 1912 the wheat grown under this name was quite widely grown in the Dakotas and Minnesota, and the name Velvet Chaff was used by the Minneapolis Chamber of Commerce and the Chicago Board of Trade as a grade name. By 1914, however, this wheat was included in the northern grades of wheat and the name Velvet Chaff was abandoned as a grade name. The name has continued in use, however, as a varietal name for the wheat on farms. The only observable difference between this wheat and the true Preston from Canada is that the latter more often shows a purple tinge in the stems and has a slightly rougher seed coat. Velvet Chaff was reported in 1919 from Idaho, Illinois, Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota,

South Dakota, Wyoming, and Wisconsin. As the name Velvet Chaff is a misnomer when applied to this type of wheat, the name Preston has been used in preference to it by the United States Department of Agriculture and by most experiment stations since 1915. It is thought by the writers that most of the wheat grown under the name of Velvet Chaff and other synonyms above recorded is really the Preston variety, although some of it is doubtless of earlier origin.

KOTA.

Description.—Plant spring habit, midseason, midtall; stem white, weak to midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, square to elevated; beaks narrow, 3 to 20 mm. long; awns 3 to 8 cm. long; kernels red, midlong, hard, ovate to elliptical, slightly humped; germ small; crease wide, usually shallow; cheeks usually angular; brush small, short to midlong.

Kota can be distinguished from Preston by the longer beaks and elevated shoulders. The kernels are more humped and have a smaller germ. Kota is resistant to many forms of stem rust and also is quite drought resistant. It also is a good milling and bread-making wheat. A spike, glumes, and kernels of Kota are shown in Plate XLI, B.

History.—The Kota variety was obtained in Russia by Prof. H. L. Bolley, of the North Dakota Agricultural College, in 1903, while making a study of the flax industry of Europe for the United States Department of Agriculture. It was introduced either as a separate lot, later designated by Professor Bolley as "R. B. R. 3," or as a mixture in a sample of durum wheat. It recently was separated from Monad durum wheat, found to be resistant to some forms of stem rust and to have high agronomic and milling values, and was named Kota in 1919 by Waldron and Clark (200, p. 187-195). The name is a part of the name North Dakota.

Distribution.—Grown to a small extent in Cass County, N. Dak., in 1920. It is also grown at several experiment stations and is used as a parent in breeding for rust-resistant spring wheats.

Synonym.—"R. B. R. 3." This is the designation used by Professor Bolley, of the North Dakota Agricultural Experiment Station, for a wheat identical with Kota. According to Professor Bolley, R. B. R. 3 was one of his original introductions from Russia in 1903, introduced as S. P. I. No. 10214.²⁴ The unpublished record for this number in the Office of Foreign Seed and Plant Introduction is "winter wheat from Balachof, Tambof Government," as one of 25 lots of wheat introduced from Russia by Professor Bolley in 1903. In 1911 Professor Bolley distributed his "R. B. R. 3" to several farmers and to the Langdon substation, but the variety never became commercially established by that distribution. In the spring of 1919, after the discovery of resistance to stem rust in Kota and its similarity to "R. B. R. 3," Professor Bolley distributed a second lot, consisting of about a bushel of seed, to Mr. Jalmer Herre, Kelso, N. Dak., who was the first farmer to increase it.

PIONEER.

Description.—Plant spring habit, early, midtall; stem usually white, a faint purple sometimes appearing on lower internodes, weak to midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong to long, narrow; shoulders wanting to narrow, oblique; beaks 1 to 5 mm. long; awns 2

²⁴ Correspondence with J. A. Clark, Office of Cereal Investigations, dated Apr. 18, 1919.

to 5 cm. long; kernels dark red, midlong, hard, ovate to elliptical; germ small to midsized; crease midwide, middeep; cheeks angular; brush midsized, short.

Pioneer differs from Preston chiefly in being several days earlier and in having a darker and harder kernel.

History.—Pioneer is of hybrid origin, having originated from the progeny of a cross made in 1903 by Dr. C. E. Saunders, Dominion cerealist, at the Central Experimental Farm, Ottawa, Canada, between Riga and Preston.

Distribution.—Grown in experiments at field stations in the northern Great Plains since 1915. It has proved to be a fair-yielding variety of high milling quality. It has not proved superior to Marquis, however, and has not become commercially grown in the United States.

RUDY.

Description.—Plant winter habit, midseason to late, midtall to tall; stem white, weak to midstrong; spike awned, linear fusiform, lax, inclined to nodding; glumes glabrous, yellowish white with black-striped margins, midlong, wide; shoulders midwide, usually oblique; beaks 1 to 5 mm. long; awns 3 to 8 cm. long; kernels red, long, soft, usually elliptical; germ small; crease wide, middeep; cheeks rounded; brush midsized, midlong.

This variety is distinct in having black stripes along the margins of the glumes. A spike, glumes, and kernels of Rudy are shown in Plate XLII, A.

History.—The origin of Rudy wheat has been recorded by Carleton (58, p. 65) as follows:

One of the best of the most recently produced varieties is the Rudy, which was originated at Troy, Ohio, in 1871, by M. Rudy, through a careful propagation of the seed from a superior and a distinct stool of wheat found in a large field.

Rudy wheat was not included in the varietal experiments of the Ohio Agricultural Experiment Station until 1892. It is reported as having been introduced into Michigan, however, from western Ohio, in 1891.

Distribution.—Grown in Arkansas, Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, Missouri, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Virginia, and West Virginia. (Fig. 60.)

Synonyms.—Anti-Rust, Black Mediterranean, Early Rudy, Kentucky Giant, and Queen of New York.

Anti-Rust is the name under which a sample of Rudy was obtained from Indiana in 1919. The name is wrongly used because the variety is not rust resistant. Black Mediterranean was also obtained from Indiana in 1919. The name is doubtless due to the black stripes on the glumes and because Rudy is very similar to Mediterranean except in glume color. Early Rudy is the name under which the Rudy variety has recently been grown by the Indiana Agricultural Experiment Station. Kentucky Giant is the name under which a sample of Rudy was obtained from Illinois in 1919. This name usually is applied to the Fulkaster variety. Queen of New York is a name under which a sample of Rudy was obtained from the Indiana Agricultural Experiment Station through the Cornell University station.

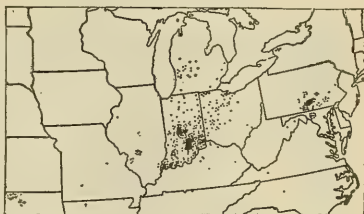


FIG. 60.—Outline map of a portion of the eastern United States, showing the distribution of Rudy wheat in 1919. Estimated area, 399,400 acres.

GLUTEN (GLUTEN B 86).

Description.—Plant winter habit, midseason, midtall to tall; stem white, midstrong; spike awned, fusiform, lax, nodding; glumes glabrous, white, midlong to long, midwide; shoulders midwide, oblique to square; beaks 2 to 15 mm. long; awns 3 to 7 cm. long; kernels red, long, soft, usually elliptical; germ small to mid-sized; crease midwide, middeep; cheeks usually angular; brush mid-sized, midlong to long.

This variety has a more nodding spike than Rudy and does not have the black stripes on the glumes.

History.—Gluten B 86 was first obtained by the United States Department of Agriculture from the Indiana Agricultural Experiment Station, in 1913, which in turn obtained it from the California station in 1902. Its origin is undetermined.

Distribution.—Grown by the Indiana and Wisconsin Agricultural Experiment Stations. It is not known to be grown commercially.

NIGGER.

Description.—Plant winter habit, midseason, midtall to tall; stem purple, midstrong to strong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, wide; shoulders midwide, oblique to square; beaks 1 to 2 mm. long; awns 2 to 6 cm. long; kernels red, long, soft, ovate to elliptical, slightly humped; germ mid-sized; crease midwide, deep, pitted; cheeks rounded to angular; brush mid-sized, midlong.

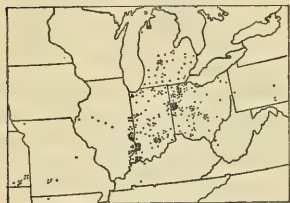


FIG. 61.—Outline map of the central United States, showing the distribution of Nigger wheat in 1919. Estimated area, 280,600 acres.

Nigger differs from Gluten and Rudy chiefly in having purple straw and shorter beaks. A spike, glumes, and kernels of Nigger are shown in Plate XLII, B.

History.—"Nigger wheat is said to have been first distributed from the farm of a colored man in Darke County, Ohio." (114, p. 4.) It was grown in experiments by the Ohio Agricultural Experiment Station as early as 1884.

Distribution.—Grown in 1919 in Arkansas, Illinois, Indiana, Kansas, Kentucky, Michigan, Missouri, Ohio, Pennsylvania, Texas, and West Virginia. This distribution is shown in Figure 61.

Synonyms.—Winter Green, Winter John, and Winter King.

Winter Green is the name under which a sample of Nigger wheat was obtained from St. Henry, Ohio, in 1919, where it had been grown for 10 years. Winter John is a name used for Nigger in Bartholomew County, Ind., since 1901. Winter King is the name under which a sample of Nigger was obtained from the Indiana Agricultural Experiment Station through the Cornell University station in 1912. Winter King was first obtained by the United States Department of Agriculture from J. A. Simmer's Seed House, Toronto, Ontario, Canada, in 1902. It was reported grown by the Ohio Agricultural Experiment Station as early as 1906, and by the Kentucky station in 1907. This name was reported in 1919 from Illinois, Indiana, Kentucky, Michigan, Missouri, Ohio, Pennsylvania, Tennessee, and West Virginia. Most of the wheat grown under this name is Goldcoin, Poole (Harvest King), Fulcaster, or Jones Fife (Winter Fife).



RUDY (A).

NIGGER (B).

Spikes, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



SILVERSHEAF (A).

GENESEE GIANT (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

SILVERSHEAF (JONES SILVER SHEAF LONGBERRY RED).

Description.—Plant winter habit, midseason, tall; stem usually white, midstrong, coarse; spike awned, fusiform, lax, inclined; glumes glabrous, white, long, midwide, easily deciduous; shoulders midwide, usually elevated; beaks 2 to 30 mm. long; awns 3 to 10 cm. long; kernels pale red, long, soft, elliptical; germ small; crease midwide, shallow to middeep; cheeks rounded; brush midsized, midlong.

The variety as grown contains mixtures of purple straw. Silversheaf is distinct in having dark coffee-colored stripes on the glumes. A spike, glumes, and kernels of Silversheaf wheat are shown in Plate XLIII, A.

History.—This variety was originated by A. N. Jones (128), Le Roy (formerly of Newark, N. Y.), Genesee County, N. Y., in 1903. Concerning it he has written the following:

I offer this season for the first time the finest Longberry Red wheat ever known in this country. . . . This wonder in the wheat line originated from a cross between my No. 8, or better known as American Bronze, and the cross-breed from a cross between Lancaster and Seedling No. 91, Longberry.

He described the wheat as follows:

Straw of a light yellow color, medium tall, thick walled and strong; head long, wide, and full, which as they ripen has a drooping habit. Chaff white, thin, with a silvery glisten in the sun; grain large, dark, and flinty, nearly as long as rye.

This wheat was advertised and distributed by Peter Henderson & Co. (110), seedsmen, of New York, as early as 1903.

Distribution.—Grown in New York and South Carolina, and under the names of synonyms in Maryland, North Carolina, Pennsylvania, and West Virginia. (Fig. 62.)

Synonyms.—Australian, Clipperd's Bearded, Coffee, and Davis.

Australian is the name under which a sample of Silversheaf was obtained from Frederick, Md., in 1919. The variety was reported under this name from Maryland and Pennsylvania. Clipperd's Bearded is the name under which a sample of Silversheaf was obtained from Chat-ham County, N. C., in 1919. Coffee is the name used for Silversheaf in West Virginia. A sample was obtained from Shepherdstown, W. Va., in 1919. The name Coffee is probably due to the color of the glumes. Davis is a name used for Silversheaf in Maryland and North Carolina. A sample of Davis was obtained from Lynch, Md., in 1919.

FRETES.

Description.—Plant spring habit, although very prostrate in early growth, midseason, midtall; stem white, weak to midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to elevated; beaks 2 to 20 mm. long; awns 2 to 7 cm. long; kernels pale red, long, soft, ovate, humped, pointed; germ small; crease midwide to wide, shallow to middeep; cheeks angular; brush midsized, midlong.

History.—Fretes was introduced into the United States from El Outaya, Constantine, Algeria, in 1901 (197, S. P. I. No. 7582) by David Fairchild and C. S. Scofield, of the United States Department of Agriculture. It is extensively grown in the oases of the Sahara Desert and is sown in November.

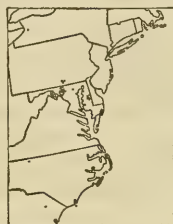


FIG. 62.—Outline map of a portion of the eastern United States, showing the distribution of Silversheaf wheat in 1919. Estimated area, 34,900 acres.

The variety is said to have originated from a shipment of Russian wheat which was made into Algeria at the time of a famine many years ago.

Distribution.—Fretes wheat has been grown in experiments at many stations in the drier sections of the United States, where it has proved a high-yielding, drought-resistant variety. Its weak straw largely has prevented it from becoming an important commercial variety. It was reported in 1919 from Los Angeles County, Calif., and was formerly grown to some extent in that county.

DIXON (HUMPBACK II).

Description.—Plant spring habit, late, tall; stem white, midstrong; spike awned, fusiform, lax, inclined; glumes glabrous, white, long, narrow; shoulders usually wanting; beaks wide, 3 to 10 mm. long; awns 4 to 7 cm. long; kernels pale red, midlong to long, semihard, ovate, humped; germ mid-sized; crease mid-wide, deep, sometimes pitted; cheeks rounded to angular; brush mid-sized, long.

This variety is distinguished by the humped kernels, the absence of shoulders on the glumes, and the wide lax spikes. The kernels have a smaller brush and germ than Humpback.

History.—The origin of Dixon is undetermined. It has been grown in Wisconsin for many years. The name Dixon is here chosen as a name for Humpback II or Smooth Humpback, as the two varieties are practically identical. The Humpback variety originated from field selections made by J. P. Berglund, a farmer living near Kensington, Minn. (190, p. 1). The original head was probably the result of a natural field hybrid. Two strains were developed, one with pubescent glumes and one with glabrous glumes. The glabrous-glumed strain was distributed a few years later than the pubescent strain, which was distributed about 1905.

Distribution.—Grown in Buffalo County, Wis. Humpback wheat was reported from Illinois, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin. Replies to the questionnaires do not show which strain of Humpback wheat is grown. It is thought by the writers, however, that this glabrous strain, Dixon, is grown to a greater extent than the true Humpback. The acreage of both strains is decreasing.

Synonyms.—Humpback II, Johnson, and Smooth Humpback. The name Humpback II was first used for this glabrous-glumed strain of Humpback in 1920 (66, p. 7). Johnson is a wheat which contains strains practically identical with Humpback II. Johnson is fully discussed under synonyms of Preston. Smooth Humpback is the name sometimes used for this glabrous-glumed strain of Humpback wheat in order to distinguish it from the pubescent strain called Humpback or Bearded Bluestem.

CHUL.

Description.—Plant spring habit, early, short to midtall; stem white, weak, spike awned, fusiform, lax, inclined; glumes glabrous, white, midlong, mid-wide; shoulders midwide, oblique to apiculate; beaks 5 to 45 mm. long; awns 3 to 10 cm. long; kernels red, long, hard, ovate, tapering, humped; germ small; crease wide, shallow; cheeks angular; brush small, midlong.

Chul differs from Talimka only in having red kernels. The kernels are large, very hard, and somewhat similar to kernels of durum wheat. A spike of Chul wheat is shown in Plate VI, Figure 1.

History.—Chul was introduced into the United States in 1902 (197, S. P. I. No. 9131) from Russian Turkestan by the United States Department of Agriculture through E. A. Bessey. The seed was obtained from Dzhizak, a town about 100 miles northwest of Samarcand. There it is grown on the steppes without irrigation and is both fall and spring sown. The original seed was a mixture

of red and white kernels, the greater part being red. The name Chul, therefore, has been continued for the red-kerneled portion. The white-kerneled types are identical with Talimka. Both types have been grown separately at experiment stations, but a part of the original introduction, which consisted of 100 pounds, was distributed to farmers. The wheat grown commercially under this name, therefore, is mostly a mixture of Chul and Talimka.

Distribution.—Chul was reported in 1919 from Lake, Siskiyou, and Yolo Counties, Calif., and Clark County, Nev.

Synonyms.—Aulieata, Idaho Hard, and Yantagbay. Aulieata (197, S. P. I. No. 9794) is a wheat identical with Chul introduced from Tashkent, Russian Central Asia, by E. A. Bessey, for the United States Department of Agriculture in 1903. Idaho Hard is a name reported for Chul from Siskiyou County, Calif. Yantagbay (197, S. P. I. No. 9791) is another wheat identical with Chul, which has the same history as Aulieata.

LINK (MISSING LINK).

Description.—Plant winter habit, late, tall; stem white, strong; spike awned, fusiform, middense, inclined; glumes glabrous, brown, midlong, midwide; shoulders midwide, oblique to square; beaks 2 to 10 mm. long; awns 3 to 7 cm. long; kernels white, midlong, soft, ovate; germ mid-sized; crease narrow to midwide, shallow to middeep; cheeks rounded; brush mid-sized, midlong to long.

History.—The origin of Link is undetermined. It was obtained as Missing Link by the United States Department of Agriculture from the Indiana Agricultural Experiment Station in 1912, which in turn obtained it from Jonas Gibson, Oakville, Ind., in 1911.

Distribution.—Grown at several experiment stations in the eastern United States and possibly commercially in Indiana, although it was not reported on the varietal survey.

EMERALD (EARLY SPRING).

Description.—Plant spring habit, midseason, midtall; stem white, slender, weak; spike awned, fusiform, middense, inclined; glumes glabrous, yellowish brown, midlong, midwide; shoulders midwide, usually oblique; beaks 1 to 3 mm. long; awns 3 to 7 cm. long; kernels white, midlong, soft to semihard, ovate; germ mid-sized; crease narrow to midwide, shallow; cheeks usually angular; brush mid-sized, short.

History.—This variety was obtained by the Nebraska Agricultural Experiment Station, Lincoln, Nebr., in 1913, from C. N. Schmale, a farmer living near Emerald, Nebr., as Early Spring wheat. Its previous history is undetermined and it is here named Emerald.

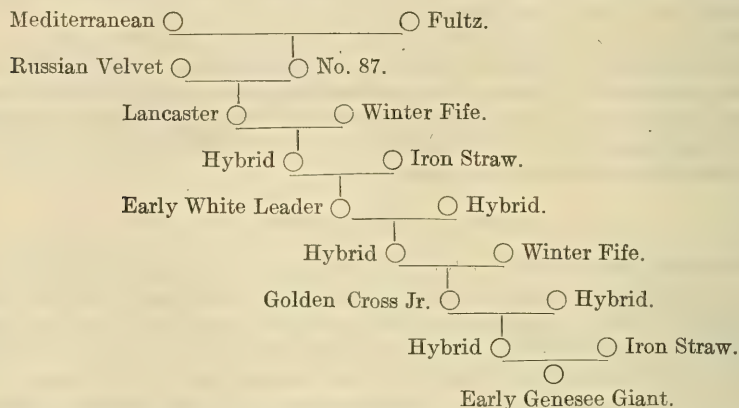
Distribution.—This variety has been grown in experiments in the State of Nebraska and has probably continued as a commercial wheat in that State, although to what extent is not known. No wheat was reported as Early Spring from Nebraska in 1919, but some white spring wheat is known to be grown in that State and this may be one of the varieties.

GENESEE GIANT (EARLY GENESEE GIANT).

Description.—Plant winter habit, midseason, midtall; stem purple, strong, stout; spike awned, clavate, dense, erect; glumes glabrous, brown, midlong, wide; shoulders narrow, usually rounded; beaks 2 to 20 mm. long; awns, 3 to 7 cm. long; kernels white, short, soft to semihard, oval; germ mid-sized; crease midwide, middeep; cheeks usually rounded; brush mid-sized, midlong; kernels produced in upper end of spikes resemble club wheat.

This variety is distinct in having a clavate spike and hard white kernels. A spike, glumes, and kernels of this variety are shown in Plate XLIII, B.

History.—Genesee Giant (Early Genesee Giant) was first distributed by A. N. Jones, of Newark, Wayne County, N. Y., the originator, in 1893. It was advertised by Peter Henderson & Co., seedsmen, of New York, in 1894, and described elaborately and recommended highly by them. It is the result of a composite cross which has been recorded by Carleton (58, p. 71), as follows:



Distribution.—Grown in Davis and Weber Counties, Utah, and experimentally in the eastern United States.

Synonyms.—Farmers Trust, Giant Squarehead, Pedigree Giant, Genesee, Golden Cross.

Farmers Trust is a local name which has recently become used for Genesee Giant in Idaho, Montana, and Nebraska. Giant Squarehead is a wheat similar to Genesee Giant obtained from the Cornell University Agricultural Experiment Station. Pedigree Giant is a wheat similar to Genesee Giant obtained from the Idaho Agricultural Experiment Station in 1912. A wheat was distributed by A. N. Jones as Pedigree Genesee Giant in 1894, the year following the distribution of Genesee Giant. This doubtless accounts for this name. It is possible that the original Genesee Giant was somewhat mixed and a pure strain was distributed later. Genesee is a shortened name used by growers in Utah. Golden Cross is the name under which a sample of wheat similar to Genesee Giant was obtained from the Indiana station through the Cornell University Agricultural Experiment Station in 1912. This name is listed for a wheat originated by A. N. Jones in 1886, heading the list of varieties which he originated, which appears on his stationery. The name Golden Cross, therefore, probably is wrongly applied to this wheat.

CANADIAN RED.

Description.—Plant spring habit, early, short; stem white, slender, weak; spike awned, oblong-fusiform, middense, inclined; glumes glabrous, brown, long, midwide; shoulders midwide, oblique to elevated; beaks 2 to 20 mm. long; awns 2 to 6 cm. long; kernels white, midlong, semihard to hard, ovate, humped, curved; germ midsized; crease middeep, shallow to middeep; cheeks rounded; brush small, short.

History.—The origin of Canadian Red is undetermined. It was obtained in July, 1919, from F. G. Stokes, of Kelseyville, Calif., who reported that it constituted 15 per cent of the wheat grown in the vicinity of Kelseyville, Lake County, Calif.

Distribution.—Grown in Lake County, Calif.

Synonym.—Canadian Spring. This name is also used for Canadian Red in Lake County, Calif.

Longberry No. 1 (Jones Longberry No. 1).

Description.—Plant winter habit, midseason, tall; stem white, midstrong; spike awned, oblong-fusiform, middense, inclined; glumes glabrous, brown, midlong, midwide; shoulders midwide, usually rounded; beaks 3 to 10 mm. long; awns 3 to 7 cm. long; kernels white, midlong to long, soft, ovate, curved; germ small to mid-sized; crease midwide, middeep, pitted; cheeks rounded; brush mid-sized, midlong to long.

History.—Longberry No. 1 was originated by A. N. Jones (128), at Newark, Wayne County, N. Y. Concerning its origin he has written as follows:

This Amber Longberry wheat sent out in bulk in 1898 has proved to be one of great value in all sections. Originating from a cross seedling, parentage of which came from a cross between Mediterranean and Russian Velvet.

Distribution.—Jones Longberry was reported grown in Kentucky, Michigan, and New York. This may or may not be Longberry No. 1.

NEW AMBER Longberry.

Description.—Plant winter habit, midseason to late, tall; stem purple, strong; spike awned, linear-fusiform, lax, inclined to nodding; glumes glabrous, brown, midlong, midwide; shoulders wanting to narrow, oblique; beaks 2 to 5 mm. long; awns 2 to 7 cm. long; kernels white, long, soft, elliptical; germ small to mid-sized; crease narrow to midwide, shallow to middeep; cheeks rounded; brush mid-sized, midlong to long.

This variety differs principally from Longberry No. 1 in having purple straw and a longer, laxer, and more fusiform spike.

History.—New Amber Longberry was obtained by the United States Department of Agriculture in 1899 from A. N. Jones, of Newark, N. Y., who is recorded as having originated it.

Distribution.—Grown in experiments at the Arlington Experimental Farm, near Rosslyn, Va. It is not known to be commercially grown.

SEVIER.

Description.—Plant spring habit, early, short to midtall; stem hollow, white, slender, weak to midstrong; spike awned, somewhat laterally compressed, oblong, dense, erect to inclined; glumes glabrous, brown, midlong, midwide; shoulders midwide, oblique; beaks midwide, acuminate, 1 to 3 mm. long; awns 2 to 6 cm. long; kernels white, midlong to long, semihard to hard, ovate, humped; germ mid-sized; crease midwide, shallow; cheeks angular; brush mid-sized, midlong.

This variety is not pure as commercially grown. It is very distinct and peculiar, as it represents nearly an intermediate form between common and durum wheat, and for that reason also somewhat resembles poulard wheat. It has the laterally compressed spike, sharply keeled glumes, and large, hard kernels of durum and the short, hollow stem, short awns, and midlong brush of common wheat. A spike, glumes, and kernels of Sevier are shown in Plate XLIV, A.

History.—The origin of Sevier wheat is undetermined. It may be the result of a natural field hybrid between common and durum wheat. It was first noted to be commercially grown in Utah by Stewart (186, p. 165) in the summer of 1918 and first listed as Kubanka durum wheat. Samples were

obtained by the writers from Mr. Stewart and from the Federal Board of Review, Chicago, Ill., and the wheat was found not to be Kubanka and was also determined to be more nearly a common than a durum wheat. As the variety had been grown in Sevier County, Utah, for 25 years or more, it was named Sevier by Stewart (187, p. 25), of the Utah station.

Distribution.—Grown in Utah.

DIEHL-MEDITERRANEAN.

Description.—Plant winter habit, midseason, midtall to tall; stem white, midstrong; spike awned, fusiform, middense, inclined to nodding; glumes glabrous, brown, midlong, midwide; shoulders midwide, rounded to oblique to elevated; beaks 1 to 8 mm. long; awns 3 to 7 cm. long; kernels pale red, midlong, soft, ovate to elliptical; germ mid-sized; crease narrow to midwide, middeep; cheeks usually rounded; brush mid-sized, midlong to long.



FIG. 63.—Outline map of a portion of the United States, showing the distribution of Diehl-Mediterranean wheat in 1919. Estimated area, 114,700 acres.

Diehl-Mediterranean differs from Mediterranean principally in having white straw and a smaller kernel. A spike, glumes, and kernels of Diehl-Mediterranean wheat are shown in Plate XLV, A.

History.—The Diehl-Mediterranean was advertised and distributed by Peter Henderson & Co., seedsmen, of New York City, for the first time in 1884, and is said by them to have originated by fertilizing the Red Mediterranean with the pollen of the Diehl (110, 1884). The same history is given in an article in the Rural New Yorker of the same year, in which it is also said that the variety originated in Monroe County, N. Y., but by whom was not noted (18). The Diehl wheat was a white-kerneled wheat with a clavate spike, probably similar to Seneca Chief. During the late eighties the Diehl-Mediterranean was distributed widely by the United States Department of Agriculture in the congressional seed distribution.

Distribution.—Grown as Diehl-Mediterranean in Michigan, New York, and Pennsylvania, and under the name of synonyms in Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Oklahoma, Tennessee, Virginia, and West Virginia. This distribution is shown in Figure 63.

Synonyms.—Auburn, Big Four, Big Ten, Blue Ridge, Eclipse, Hybrid Mediterranean, Michigan Bronze, Michigan Brown, Miller's Choice, Rattle Jack, Russian Amber, Shepherd's Perfection, Shepherd's Prolific, and Spade.

Auburn is the name under which a wheat identical with Diehl-Mediterranean was obtained from the Virginia Agricultural Experiment Station in 1917. It is not known to be commercially grown. Big Four, which also was found to be identical with Diehl-Mediterranean, was obtained from A. J. Hagman, of Hawesville, Hancock County, Ky., who stated that it had been grown for eight years in that vicinity, where it constitutes 33 per cent of the wheat acreage. It also is grown in Cass County, Ind. Big Ten also is Diehl-Mediterranean, as grown in Ripley County, Ind., and Henderson County, Ky. Blue Ridge is a name under which samples of wheat similar to Diehl-Mediterranean have been obtained from the Kentucky and Virginia stations. Its further history is undetermined. Blue Ridge was reported in 1919 from North Carolina, New Jersey,



SEVIER (A).

LADOGA (B).

Spike, face view, natural size; plumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



DIEHL-MEDITERRANEAN (A).

GOENS (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

and Pennsylvania. Eclipse is a wheat similar to Diehl-Mediterranean, except that sometimes it has a slightly elevated shoulder. This wheat was first obtained by the United States Department of Agriculture from T. W. Wood & Sons, seedsmen, of Richmond, Va., in 1899. Its previous history is undetermined. Eclipse was reported from Ohio, Tennessee, Virginia, and West Virginia. Hybrid Mediterranean is a name early used for Diehl-Mediterranean wheat and often is referred to in literature as a synonym of that variety.

Michigan Bronze is a name which was recognized as a synonym of Diehl-Mediterranean wheat by the Ohio Agricultural Experiment Station as early as 1888. It apparently is a name under which Diehl-Mediterranean wheat was advertised and distributed by Thorburn & Co., seedsmen, of New York City, as early as 1889. The name, however, was recorded for a wheat by C. S. Plumb as early as 1877. It was reported from Michigan and Tennessee in 1919. Michigan Brown apparently is a name used by some growers of Michigan Bronze.

Miller's Choice apparently is identical with Diehl-Mediterranean. It has been grown by the North Carolina Agricultural Experiment Station, but was not reported in the varietal survey. According to Prof. G. M. Garren, of North Carolina station, the wheat now called Miller's Choice was bought as seed wheat by B. B. Miller, of Salisbury, N. C., from some one in Maryland, who called it "Spade" wheat. It was tried on Mr. Miller's place and later on the Iredell Farm of the North Carolina station at Statesville, N. C., and did well in each place. As the name "Spade" was not familiar to these men, it was rechristened "Miller's Choice," in honor of Mr. Miller.

Rattle Jack is the same as Diehl-Mediterranean and is the principal variety grown in Crawford County, Kans. It also is grown in Cherokee and Neosho Counties, Kans., and Osage County, Okla. It was also reported from Madison and Marion Counties, Ill., but according to Leighty the wheat there grown as Rattle Jack is of Gipsy type. Its history is undetermined. Russian Amber is a name under which samples of wheat identical with Diehl-Mediterranean have been received from the Indiana Agricultural Experiment Station. Its history is undetermined and it is not known to be commercially grown. Shepherd's Perfection grown in 14 counties in Michigan is for the most part Diehl-Mediterranean. One sample obtained from Ceresco, Calhoun County, proved to be Goens. Shepherd's Prolific is a name under which a sample identical with Diehl-Mediterranean was obtained from the Indiana Agricultural Experiment Station. It was reported from Jennings County, Ind., and Delaware and Richland Counties, Ohio. Spade is identical with Diehl-Mediterranean. The origin of the name Spade is undetermined. Wheat under that name was first obtained by the United States Department of Agriculture from Pennsylvania in 1903. It was reported from Georgia, Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, Tennessee, and Virginia.

RUSSIAN.

Description.—Plant winter habit, late, midtall; stem white, strong; spike awned, fusiform, middense, inclined; glumes glabrous, brown, midlong, narrow; shoulders wanting to narrow, elevated; beaks 2 to 10 mm. long; awns 3 to 7 cm. long; sometimes black; kernels red, midlong, semihard, ovate to elliptical, acute; germ small; crease midwide, shallow to middeep; cheeks rounded to angular; brush mid-sized, midlong to long.

Russian differs from Diehl-Mediterranean principally in being later and shorter and in having narrower and darker colored glumes and, under some conditions, black awns.

History.—The above-described sample under the name of Russian was obtained from the Virginia Agricultural Experiment Station, Blacksburg, Va., in 1917. Its origin is undetermined. It is slightly different from Russian Amber listed above as a synonym of Diehl-Mediterranean, and also is different from any other wheat grown in the United States under the name of Russian.

Distribution.—Wheat under the name Russian was reported in 1919 from Maryland, Michigan, Missouri, Ohio, Tennessee, and Virginia. This may or may not be the wheat above described.

IMPERIAL AMBER.

Description.—Plant winter habit, midseason, midtall; stem usually white, sometimes faintly purple on lower internodes, midstrong; spike awned, broadly fusiform, middense, inclined; glumes glabrous, brown, long, wide; shoulders wanting to narrow, oblique; beaks 3 to 25 mm. long; awns 2 to 8 cm. long; kernels red, midlong, soft, ovate to elliptical; germ small to mid-sized; crease midwide, middeep to deep, pitted; cheeks usually rounded; brush mid-sized, midlong.

Imperial Amber differs from Diehl-Mediterranean principally in having longer glumes and beaks.

History.—The origin of Imperial Amber is undetermined. Several samples have been obtained from the Missouri and Indiana Agricultural Experiment Stations. The samples have varied slightly in length of beak and other minor characters. The strain above described is a pure-line selection (C. I. No. 5338) made by Dr. C. E. Leighty at the Arlington Experimental Farm from a bulk sample obtained from the Missouri Agricultural Experiment Station in 1913.

Distribution.—No wheat is known to be grown commercially under the name Imperial Amber. The unselected wheat under this name, which probably may be only Diehl-Mediterranean, has been grown in experiments in Missouri, Indiana, Ohio, and New York, and the pure-line strain above described is grown at Arlington Farm.

Synonyms.—Davidson and Farmers Trust. A sample of wheat called Davidson was obtained from the Virginia Agricultural Experiment Station in 1917 and proved to be very similar to Imperial. The origin of Davidson is undetermined and it is not known to be commercially grown. Farmers Trust is a name under which a sample similar to Imperial was obtained from the Cornell University Station. This name is applied to at least two other varieties. It probably is most commonly used for Mediterranean. The name was reported for wheat grown in Arkansas, Indiana, Michigan, Pennsylvania, and Wisconsin.

GOENS.

Description.—Plant winter habit, early, midtall to tall; stem purple, strong; spike awned, fusiform, middense, inclined; glumes glabrous, brown, midlong to long, midwide, easily deciduous; shoulders narrow, usually oblique; beaks 1 to 3 mm. long; awns 2 to 7 cm. long; kernels red, midlong, soft, ovate; germ mid-sized to large; crease midwide, middeep to deep, sometimes pitted; cheeks usually rounded; brush mid-sized, midlong.

Goens differs from Diehl-Mediterranean principally in being earlier and in having purple straw, more easily shattered spikes, and shorter beaks. A spike, glumes, and kernels of Goens are shown in Plate XLV, B.

History.—The Goens variety, under the names Red Chaff and Red Chaff Bearded, has long been known in the United States. According to Klippart, in 1857 (*131*, p. 739) this wheat was "cultivated in Clermont County, Ohio, for upward of 50 years." He further states that the origin of the name Goens is undetermined. Wheat under this name was first obtained by the United States

Department of Agriculture in 1912 from the Indiana Agricultural Experiment Station, through Cornell University. It "was introduced into Muskingum County (Ohio) by John Dent in 1808." The Red Chaff wheat mentioned above, however, may be only the Mediterranean variety, as Goens has been said to be a cross between Mediterranean and Gipsy made by a man named Goens in Ohio and afterwards developed by his son. Concerning the introduction of the variety into Shelby County, Ind., where it now is the leading variety, Russell G. East, county agent, Shelbyville, Ind., has written as follows:²⁵

Answering your inquiry regarding Shelby Red Chaff wheat. The year 1887 a man named Hall living at Fountaintown, in this county, purchased a carload of seed wheat in Paulding County, Ohio. From this start this variety has become the common variety grown throughout the county and has been known locally as Hall, Red Hall, Red Chaff, and Red Chaff Bearded.

Distribution.—Grown as Goens in Indiana, Michigan, and Ohio, and under the names of synonyms in Illinois and Pennsylvania. (Fig. 64.)

Synonyms.—Baldwin, Cummings, Dunlap, Dunlop, Going, Hall, Miller's Pride, Owen, Red Chaff, Red Chaff Bearded, Red Hall, and Shelby Red Chaff. The name Baldwin is used locally for Goens wheat in Madison, Pickaway, and Union Counties, Ohio. Cummings is the name of a wheat apparently identical with Goens which was reported grown for two years in the vicinity of Tippecanoe City, Miami County, Ohio, and constitutes 50 per cent of the wheat of that vicinity, according to C. A. Studebaker, of that place. Dunlap is the name under which a sample of wheat identical with Goens was obtained from the Indiana Agricultural Experiment Station in 1913. It is grown in Indiana, Ohio, and Pennsylvania as Dunlap or Dunlop. In Fayette and Rush Counties, Ind., it is extensively grown. The names Going and Owen are commonly used on Ohio farms for Goens. Hall and Red Hall are names used for a wheat identical with Goens in Indiana, particularly in Hancock and Shelby Counties, where it is extensively grown and where it has been grown for 10 to 15 years. According to J. E. Barrett, of Fortville, Ind., the variety was named Hall for J. M. Hall, the man who first took the wheat into Hancock County. Miller's Pride also is identical with Goens and is grown in Berks County, Pa. A sample of this wheat was first obtained by the United States Department of Agriculture in 1912 from Cornell University, which in turn obtained it from the Indiana station. Red Chaff and Red Chaff Bearded, as indicated above, are old names now most commonly used for Goens wheat in Indiana, Ohio, and Illinois. Red Chaff was reported from several other States, but as this name is used also for other varieties, the distribution of Goens wheat as Red Chaff can not be definitely determined. Shelby Red Chaff is the name adopted by the farm bureau executive board of Shelby County, Ind.

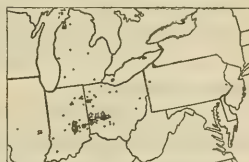


FIG. 64.—Outline map of a portion of the eastern United States, showing the distribution of Goens wheat in 1919. Estimated area, 132,600 acres.

COX.

Description.—Plant winter habit, late, midtall; stem purple, midstrong; spike awned, oblong to clavate, dense, inclined to nodding; glumes glabrous, brown, midlong, midwide; shoulders narrow, oblique to square; beaks 1 to 10 mm. long; awns 3 to 6 cm. long; kernels red, midlong, soft, ovate to oval to elliptical; germ mid-sized; crease narrow, middeep; cheeks usually rounded; brush mid-sized, midlong.

Cox differs principally from Goens in having an oblong to clavate spike and longer beaks.

²⁵ Correspondence of the Office of Cereal Investigations, Mar. 1, 1922.

History.—A sample of this wheat was first obtained by the United States Department of Agriculture from a Mr. Ruppe, of Pendleton, Oreg., in 1900, at which time the wheat evidently was a commercial variety in that vicinity. Recent samples have been obtained from Hustis A. Miller, of Lexington, Morrow County, Oreg., who states that it has been grown in that county since about 1906. Its previous history is undetermined.

Synonym.—Cox Red Crown. This name was used by Hyslop (126, p. 674) in referring to the Cox variety.

Distribution.—Cox wheat was reported in 1919 from Morrow and Umatilla Counties, Oreg.

YAROSLAV.

Description.—Plant winter habit, late, midtall to tall; stem purple, midstrong, slender; spike awned, fusiform, middense, inclined to nodding; glumes glabrous, brown, sometimes striped with black, short, narrow; shoulders midwide, usually rounded; beaks 1 to 3 mm. long; awns 3 to 7 cm. long, sometimes black; kernels red, midlong, semihard to hard, narrowly ovate; germ small; crease narrow to midwide, shallow to middeep; cheeks usually rounded; brush small, midlong.

Yaroslav somewhat resembles Turkey, but differs principally from it in having brown glumes and softer kernels.

History.—Yaroslav wheat was introduced into the United States in 1899 from Russia by M. A. Carleton (59, p. 20) for the United States Department of Agriculture. This wheat was obtained in two localities in the Governments of Yaroslav and St. Petersburg (197, S. P. I. Nos. 2791 and 2792.) It was reported to have been very winter hardy in Russia, and it was introduced for the object of replacing spring wheat in Iowa, northern Nebraska, and South Dakota. The wheat evidently did not prove winter hardy in that section of the United States.

Distribution.—Grown in experiments by the Colorado Agricultural Experiment Station at Fort Collins, Colo. It is not known to be commercially grown, except as occasional mixtures in Turkey and other Crimean wheats.

HURON.

Description.—Plant spring habit, midseason, midtall; stem white, slender, midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, brown, short, narrow; shoulders midwide, oblique to square; beaks 1 to 3 mm. long; awns 3 to 8 cm. long; kernels red, usually short, semihard to hard, ovate, acute; germ small to mid-sized; crease narrow to midwide, shallow; cheeks usually rounded; brush small, short to midlong.

History.—Huron wheat resulted from the progeny of a cross made in 1888 between White Fife and Ladoga, at the Central Experimental Farm, Ottawa, Canada. The cross was made by A. C. Saunders under the direction of his father, Dr. William Saunders, Dominion cerealist (50, p. 149). The Huron variety was first entered in the varietal experiments at Indian Head, Saskatchewan, in 1894.

Distribution.—Grown in experiments in North Dakota, South Dakota, and Montana. It is not known to be commercially grown in the United States, but is grown to a small extent in the Prairie Provinces of Canada.

NORKA.

Description.—Plant spring habit, midseason, midtall; stem white, weak to midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, brown,

midlong, midwide; shoulders midwide, oblique to elevated; beaks 3 to 25 mm. long; awns 3 to 8 cm. long; kernels red, short to midlong, hard, ovate, acute; germ small to midsized; crease narrow to midwide, shallow; cheeks usually angular; brush small; short to midlong.

History.—The Norka variety originated from a pure-line selection of common wheat separated from a plat of Kubanka durum wheat in 1908 by W. G. Shelley, then a representative of the United States Department of Agriculture, at Akron, Colo. The name is the reverse spelling of Akron (66, p. 7).

Distribution.—Grown in experiments in Colorado, Wyoming, North Dakota, South Dakota, and Montana. It is not commercially grown.

LADOGA.

Description.—Plant spring habit, early to midseason, midtall; stem faintly purple on lower internodes, midstrong; spike awned, fusiform, middense, inclined to nodding; glumes glabrous, brown, short to midlong, narrow; shoulders narrow, usually rounded; beaks variable; awns 2 to 9 cm. long; kernels red, midlong, hard, ovate; germ midsized; crease midwide, middeep; cheeks usually angular; brush small, midlong.

All commercial samples of Ladoga wheat are variable in beak length, as stated above, ranging from 1 to 5 mm. to as long as 3 to 25 mm. in length. A pure-line selection obtained from Dr. C. E. Saunders, of Ottawa, Canada, has beaks only 1 to 2 mm. long. A spike, glumes, and kernels of Ladoga are shown in Plate XLIV, B.

History.—Ladoga wheat was introduced into Canada from Russia, where it was grown in latitude 60° N., near Lake Ladoga, north of Petrograd, about 1888. It was sent by the Canadian Department of Agriculture to several hundred farmers in northwestern Canada from 1888 to 1893, in the hope that it would provide a wheat ripening about 10 days earlier than Red Fife (168). By 1893, milling tests of the variety had shown that it was of poor milling quality, and after that time the further distribution of the variety was not encouraged.

Distribution.—Grown commercially in the United States, but only under the name Spring Turkey, in Colorado, Kansas, Montana, Nebraska, and Wyoming.

Synonyms.—Bastard and Spring Turkey. Bastard is the name applied to a wheat apparently identical with Ladoga, which is commonly found mixed in varieties of hard spring wheat in North Dakota and Montana. This mixture is thought by the authors to be remnants of Ladoga wheat which came down from Canada during the early years of wheat production in these northwestern States. Spring Turkey is the name used for wheat apparently identical with Ladoga, which is grown both as mixtures and pure in Montana and Wyoming. The authors are of the opinion that this is the Ladoga variety. Spring Turkey was reported in 1919 from Colorado, Kansas, Montana, Nebraska, and Wyoming.

LARAMIE.

Description.—Laramie is similar to Ladoga, except that it has weaker straw, an elevated shoulder, and beaks 2 to 20 mm. long.

History.—Laramie is the result of a pure-line selection from the commercial wheat grown in Wyoming as Spring Turkey. The selection was made by J. W. Jones, a representative of the United States Department of Agriculture at the Cheyenne Experiment Farm, Archer, Wyo., in 1914. The wheat was named for Laramie County, Wyo. (66, p. 7).

Distribution.—The Laramie variety is grown in experiments in Colorado, Montana, South Dakota, and Wyoming, but is not commercially grown.

ARIETTE.

Description.—Plant winter habit, midseason, midtall; stem white, midstrong; spike awned, fusiform, lax, inclined to nodding; glumes glabrous, brown, midlong, midwide; shoulders midwide, oblique to elevated; beaks 1 to 10 mm. long; awns 2 to 10 cm. long; kernels red, midlong to long, usually semihard, ovate; germ midsized; crease midwide, middeep; cheeks angular; brush midsized, midlong.

History.—Ariette presumably is of Italian origin. It was obtained by the Portland Seed Co. from Italians in the vicinity of Portland, Oreg., who claim to have introduced it from Italy, where it is known as Ariette.

Distribution.—Said by the Portland Seed Co. to be grown in the vicinity of Portland, Oreg. They sold seed of the variety for a number of years.

Synonyms.—Aulieata. This is the name under which the Portland Seed Co. sold seed of the Ariette variety in 1919. They submitted a sample of the wheat to the Oregon Agricultural Experiment Station for identification and were informed that it probably was Aulieata. They, therefore, advertised it under that name in 1919. It was later determined, however, that it was not Aulieata.

MEDITERRANEAN.

Description.—Plant winter habit, midseason, tall; stem purple, midstrong, coarse; spike awned, fusiform, middense, erect to inclined; glumes glabrous, brown, long, midwide, easily deciduous; shoulders wanting to narrow, oblique; beaks 1 to 8 mm. long; awns 3 to 7 cm. long; kernels red, long, soft, elliptical; germ midsized; crease midwide, middeep; cheeks rounded; brush midsized, midlong.

A spike, glumes, and kernels of Mediterranean are shown in Plate XLVI, A.

History.—Reference to the Mediterranean variety in American literature begins in 1842, when the variety was widely grown, with the statement that it had been introduced some years before. One writer says (103, p. 228) it was introduced into Maryland from the Mediterranean Sea region in 1837. In 1863 it was recorded (141, p. 501) that it was introduced in 1819 from Genoa, Italy, by John Gordon, of Wilmington, Del. It came into prominence in New York between 1845 and 1855, from which time its culture spread rapidly westward. Its early popularity apparently was gained because it was more resistant to Hessian fly damage than other varieties. It was found also to be several days earlier than the commonly grown winter wheats, such as the Flint, Bluestem, Red Bluestem, Golden Straw, and other wheats grown at that time. It was called rust resistant probably because of its earliness, and was commended as a high yielder of especially heavy grain and adapted to poorer soils than most varieties. White wheats being the standard, it was vigorously criticized, especially by millers, because its red kernels yielded a dark flour and because of the thickness of the bran. This disapproval persisted for at least 25 years, but after the introduction of roller mills it became recognized as a good milling wheat. In the earlier years it became known under many different names, as Bearded Mediterranean, Red Mediterranean, and Red Chaff Mediterranean, to distinguish it from other and different varieties to which the name Mediterranean became attached. Other synonyms were Columbian and Quaker in Pennsylvania and German in Maryland. These names apparently now have gone out of use. This early confusion in names probably was the result of repeated introductions.

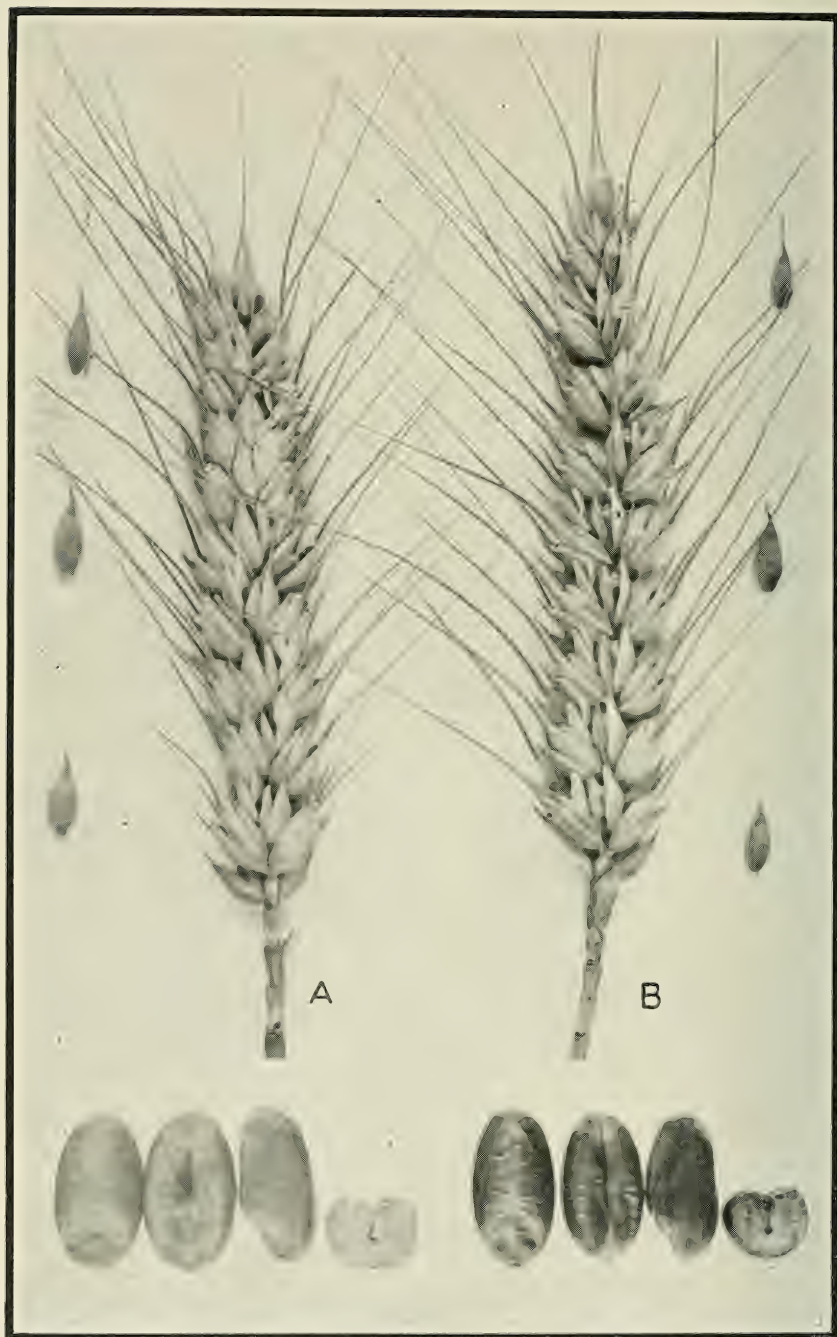
Distribution.—Grown in Alabama, Arkansas, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Missis-



MEDITERRANEAN (A).

RED ROCK (B).

spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



READ (A).

RURAL NEW YORKER No. 57 (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

issippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, Tennessee, Texas, Virginia, and West Virginia. This distribution is shown in Figure 65.

Synonyms.—Acme, Bluestem, Farmers Trust, Great Western, Key's Prolific, Lancaster Red, Lehigh, Miller, Miller's Pride, Missouri Bluestem, Mortgage Lifter, Red Chaff, Red Sea, Red Top, Rocky Mountain, Standby, and Swamp.

Acme is a name reported for Mediterranean wheat from Pennsylvania. Bluestem is a name commonly used by farmers in the eastern United States for Mediterranean, as well as for several other wheat varieties. Farmers Trust is a name which has been used in the central United States for Mediterranean wheat during the last 15 or 20 years. It was reported from Arkansas, Indiana, Michigan, Pennsylvania, and Wisconsin. Great Western was reported from Virginia for Mediterranean. Key's Prolific is a name used for Mediterranean in Harford

County, Md. Lehigh is a name which has been used for Mediterranean wheat for about 20 years, but which evidently is no longer used by growers. It is still grown under this name by some experiment stations. Lancaster Red was reported by Dietz in 1869 (6, p. 178) as "a variety of the Red Chaff Bearded Mediterranean. It was obtained by selecting from the field in Lancaster County, Pa."

Miller is a name used for Mediterranean in Frederick County, Md. Miller's Pride is the name under which several samples of Mediterranean wheat have been received from the Indiana Agricultural Experiment Station. Its previous history is not determined. It was reported from Berks County, Pa. Missouri Bluestem is the name under which a wheat similar to Mediterranean, except for slightly shorter spikes, has been grown at the Arlington Experimental Farm, Va., and College Park, Md., for a number of years. The original seed was obtained from Stamford, Conn., in 1899. It is not known to be commercially grown. Mortgage Lifter is a name used for Mediterranean in Center County, Pa. Red Chaff is a name commonly used for Mediterranean as well as several other varieties of wheat. The distribution of Mediterranean under the name Red Chaff, therefore, can not be definitely determined. Red Sea is a name long used for Mediterranean wheat. How and when its use became established is not known. It was reported in 1919 from Arkansas, Illinois, Kansas, Missouri, Oklahoma, Rhode Island, Tennessee, and Texas. Red Top is a name used for Mediterranean in Oklahoma.

Rocky Mountain is the name under which a wheat identical with Mediterranean, except for a slightly shorter spike, has been grown at the Federal and

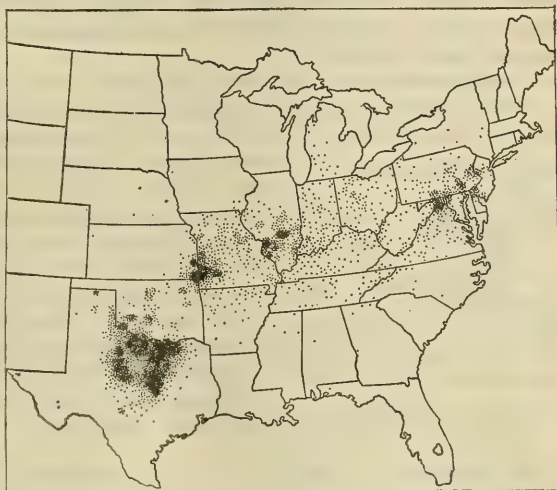


FIG. 65.—Outline map of the eastern United States, showing the distribution of Mediterranean wheat in 1919. Estimated area, 2,558,900 acres.

State experiment stations, at Arlington Farm, Va., and College Park, Md., since 1908. The original sample is of Maryland origin, obtained about 1900. Apparently the name Rocky Mountain was in use at that time for Mediterranean wheat. It was reported in 1919 from Illinois, North Carolina, Pennsylvania, Tennessee, and Virginia. Standby is a name used for Mediterranean in West Virginia. Swamp is a name commonly used, particularly in Indiana, for Mediterranean wheat. It was advertised by J. A. Everitt's Seed Store, of Indianapolis, Ind., in their fall catalogue of 1899, and probably was distributed for several years previous to that time. It was reported in 1919 from Illinois, Indiana, Kentucky, Ohio, Tennessee, and West Virginia.

RED ROCK.

Description.—Red Rock is similar to Mediterranean except for a slightly longer, wider, and laxer spike and a harder kernel which has a wider and deeper crease. It also yields better and is superior to Mediterranean for milling and bread making.

A spike, glumes, and kernels of Red Rock are shown in Plate XLVI, B.

History.—Red Rock was originated at the Michigan Agricultural Experiment Station, Lansing, Mich., from an individual kernel picked out of a white wheat called Plymouth Rock. The selection was first sown in the fall of 1908. By 1914, 60 bushels were sent out by the experiment station to as many farmers, 1 bushel being furnished each farmer. In 1915, 69 bushels were distributed in the same way. It is estimated that in the fall of 1915, 1,000 bushels of Red Rock wheat were sown in the various parts of the State of Michigan (184, p. 3).



FIG. 66.—Outline map of a portion of the northern United States, showing the distribution of Red Rock wheat in 1919. Estimated area, 216,000 acres.

Distribution.—Reported in 1919 from 68 counties in Michigan and from Connecticut, Illinois, Indiana, and Ohio. (Fig. 66.)

BEARDED WINTER FIFE.

Description.—Plant winter habit, midseason, mid-tall; stem white, strong, stout; spike awned, oblong-fusiform, middense, nodding; glumes pubescent, white, midlong, midwide; shoulders midwide, usually square; beaks 2 to 10 mm. long; awns 3 to 7 cm. long; kernels white, midlong, soft, broadly ovate; germ small to mid-sized; crease midwide, middeep; cheeks rounded; brush large, midlong.

History.—Bearded Winter Fife was originated by A. N. Jones,²⁰ of Newark, N. Y., in 1894, and, according to Carleton (61, p. 221), it is of hybrid origin and has Jones Fife as one parent. The Bearded Winter Fife was first distributed in 1896 by Peter Henderson & Co., seedsmen, of New York City.

Distribution.—Grown at experiment stations in the eastern United States. It is also probably commercially grown to a small extent, but as it has become so confused with other varieties, a definite distribution can not be reported.

READ (READ'S VERMONT WINTER).

Description.—Plant winter habit, midseason, short; stem white, strong, stout; spike awned, clavate, dense, inclined; glumes pubescent, white, long, wide; shoulders narrow, oblique; beaks 2 to 10 mm. long; awns 2 to 5 cm.

²⁰ Printed stationery of Mr. A. N. Jones.

long; kernels white, midlong, soft, broadly ovate to oval; germ large; crease narrow, middeep, pitted; cheeks rounded; brush large, midlong to long.

Read differs principally from Bearded Winter Fife in being shorter and in having a distinctly clavate spike. A spike, glumes, and kernels of Read wheat are shown in Plate XLVII, A.

History.—Read (Read's Vermont Winter) was developed and named by Mr. G. A. Read, of Charlotte, Vt., who recorded the history as follows:²⁷

This wheat was originated by me in 1898 by crossing the Bearded Fife with a valuable early club-head beardless velvet-chaff variety found mixed with Bearded Fife and presumably Early Arcadian.

Distribution.—Grown in Ashland County, Ohio, where it constitutes about 5 per cent of the wheat grown in the vicinity of New London.

RURAL NEW YORKER NO. 57.

Description.—Plant winter habit, midseason, midtall to tall; stem white, strong, stout; spike awned, fusiform, middense, nodding; glumes pubescent, white, long, midwide; shoulders narrow, usually oblique; beaks 2 to 15 mm. long; awns 3 to 7 cm. long; kernels red, midlong, soft to semihard, ovate to oval; germ mid-sized; crease usually wide, middeep to deep; cheeks usually rounded; brush large, midlong.

A spike, glumes, and kernels of Rural New Yorker No. 57 are shown in Plate XLVII, B.

History.—The following quotation from the Rural New Yorker, in 1894 (25, p. 634), shows the origin of this variety:

Peter Henderson & Co., of this city, now offer for the first time two of our wheats which the firm has kindly named "Rural New Yorker No. 57" and "Rural New Yorker No. 6." The first, of which an excellent portrait is presented in Figure 166, p. 631, is a heavily bearded variety, the parentage of which is one of our crossbred varieties fertilized with a cross breed of Velvet Chaff.

Further information concerning the origin of the variety is given by Peter Henderson & Co., in their 1895 catalogue, as follows:

Rural New Yorker No. 57 is the result of upwards of 20 years of thoroughly scientific crossing and careful selection at the hands of Mr. E. S. Carman, editor of the Rural New Yorker and raiser of many of the most valuable agricultural introductions of recent years.

A simplification of the name Rural New Yorker No. 57 would be made here if the variety had not already practically passed out of cultivation.

Distribution.—Rural New Yorker No. 57 is grown at several experiment stations in the eastern United States and probably is grown commercially to a small extent, although this is not definitely known.

Synonym.—Velvet Chaff. This name has been used for wheat identical with Rural New Yorker No. 57, as well as for several other varieties. It is quite possible that a wheat of this type was commercially grown in the eastern United States many years before the origin of Rural New Yorker No. 57. A sample called Velvet Chaff obtained from the West Virginia Agricultural Experiment Station in 1917 proved to be similar to Rural New Yorker No. 57, except in having faintly purple straw. The previous history of this sample is undetermined.

PRIDE OF GENESEE.

Description.—Pride of Genesee is similar to Rural New Yorker No. 57, except that the beaks are slightly longer and the kernels slightly wider.

²⁷ Printed circular by G. A. Read.

History.—Pride of Genesee was originated by A. N. Jones,²⁸ of Newark, Wayne County, N. Y., in 1893. Whether or not it is of hybrid origin is not known.

Distribution.—Grown in Monroe County, N. Y.

VIRGINIA.

Description.—Virginia is similar to Rural New Yorker No. 57, except that the quality of the grain is better.

History.—Virginia is the result of a cross between an unnamed wheat (C. I. No. 1344) and Jones Fife, made by H. A. Miller, in 1905, who was then a representative of the United States Department of Agriculture at the Maryland Agricultural Experiment Station, College Park, Md., where the cross was made (185, p. 20).

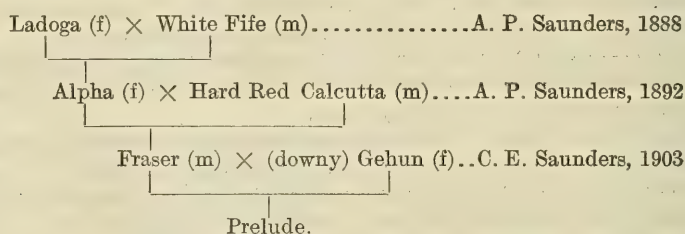
Distribution.—The variety is grown in experiments in Virginia, West Virginia, Tennessee, and Arkansas, and small quantities have been distributed for commercial growing.

PRELUDE.

Description.—Plant spring habit, early, short; stem usually white, sometimes faintly purple on lower internodes, strong; spike awned, fusiform, middense, erect; glumes pubescent, yellowish, midlong, midwide, easily deciduous; shoulders narrow, oblique to square; beaks 2 to 5 mm. long; awns black, 2 to 5 cm. long; kernels dark red, short, hard, ovate, truncate; germ mid-sized; crease midwide, shallow to middeep, triangular; cheeks angular; brush small, short.

Prelude is distinct by its early maturity and its black awns. It shatters badly and therefore always should be harvested before it is entirely ripe. It usually is a low-yielding variety, but is well adapted to northern latitudes, where its earliness enables it to escape fall frosts. It also has shown to advantage in experiments on the southern border of the spring-wheat sections of the Great Plains area, where early maturity is an important factor. It is an excellent milling and bread-making variety (Pl. XLVIII, 4).

History.—Prelude was originated by Dr. C. E. Saunders, cerealist of the Dominion Department of Agriculture, at the Central Experimental Farm, Ottawa, Canada (167, p. 118). The parentage of Prelude is shown by Buller (50, p. 186), as follows:



Prelude was first distributed in 1913. It was introduced into the United States by the United States Department of Agriculture in 1915 for experimental purposes.

Distribution.—Prelude is grown at experiment stations in the northern spring-wheat sections of the United States. It is grown commercially in Minnesota and Wisconsin under the name of Wisconsin Wonder.

²⁵ Printed stationery of Mr. A. N. Jones.



PRELUDE (A).

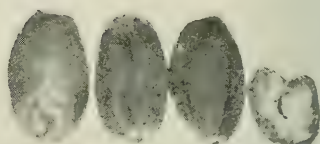
HUMPBACK (B).

Spike, face view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



A

B



HYBRID 128 (A).

HYBRID 143 (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

Synonym.—Wisconsin Wonder. Prelude wheat has been distributed as Wisconsin Wonder by H. E. Krueger, of Beaver Dam, Wis. In advertising the variety Mr. Krueger claims to have originated it from the selection of a plant grown in a field of Marquis about 1910. The distribution of Wisconsin Wonder wheat dates from 1916. It was reported in 1919 from seven counties in Wisconsin.

HUMPBACK.

Description.—Plant spring habit, late, tall; stem white, midstrong; spike awned, fusiform, middense to lax, inclined; glumes pubescent, white, long, midwide; shoulders usually wanting, sometimes narrow, oblique; beaks 2 to 8 mm. long; awns 3 to 8 cm. long; kernels pale red, midlong to long, semihard, ovate, humped; germ large; crease midwide, deep, pitted; cheeks rounded to angular; brush small, long.

This variety is distinct because of its pubescent glumes and its rather large, soft kernels, which are distinctly humped. It is a very poor milling and bread-making variety. A spike, glumes, and kernels of Humpback are shown in Plate XLVIII, B.

History.—The Humpback variety originated from field selections made by J. P. Berglund, a farmer living near Kensington, Minn. (190, p. 1). The original head was probably the result of a natural field hybrid. Two strains were developed, the first being the strain above described, which was distributed about 1905. The second has glabrous glumes, but is otherwise similar. It is described elsewhere as Dixon.

Distribution.—Humpback wheat was reported sparingly grown in Illinois, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin. (Fig. 67.)

Synonyms.—Bearded Bluestem and World Beater. Bearded Bluestem is the name by which the variety was first distributed by Mr. Berglund, but the name Humpback soon became attached to the variety and the use of the name Bearded Bluestem largely has been discontinued. World Beater is the name under which a wheat practically identical with Humpback was obtained from a farmer named Bruegger, in the vicinity of Williston, N. Dak., in 1913. At that time World Beater was cultivated to a small extent in that locality. It was not reported in 1919.



FIG. 67.—Outline map of the north-central United States, showing the distribution of Humpback wheat in 1919. Estimated area, 31,900 acres.

PENQUITE (PENQUITE'S VELVET CHAFF).

Description.—Plant winter habit, midseason, midtall; stem purple, midstrong; spike awned, fusiform, middense, nodding; glumes pubescent, brown, long, midwide, easily deciduous; shoulders wanting to narrow, usually oblique; beaks 1 to 2 mm. long; awns 3 to 7 cm. long; kernels red, midlong, soft, ovate, humped; germ mid-sized; crease midwide, middeep; cheeks rounded; brush small, midlong.

History.—According to Thorne (192, p. 618):

This wheat originated in Clinton County, Ohio, where in 1857 or 1858 Mr. Abram Penquite, while cradling in a field of wheat, noticed three heads of a different variety from the rest of the field. These he saved and propagated, and from them has come the wheat now widely known in southwestern Ohio as the Velvet Chaff.

Distribution.—Several varieties are grown under the name of Velvet Chaff. Winter wheat of this description was sparingly reported as Velvet Chaff from Alabama, Arkansas, Georgia, Illinois, Indiana, Kentucky, Louisiana, Maryland, Missouri, Ohio, Oklahoma, Pennsylvania, and Tennessee.

Synonyms.—Japanese Velvet Chaff and Velvet Chaff. Japanese Velvet Chaff is the name under which a wheat identical with Penquite was obtained by the United States Department of Agriculture at the Paris Exposition, held in France, in 1900. It has been grown in experiments in Virginia and Maryland, but is not known to be commercially grown.

Velvet Chaff is the name under which Penquite (Penquite's Velvet Chaff) has been best known in Ohio since about 1880. Although the name Velvet Chaff has become generally used for the variety, it is also confused with, and used for, other varieties, and for these reasons the name Penquite is here adopted.

CLUB WHEAT.

The plants of club wheat may be either winter or spring habit, and either tall or short. The straw is stiff and strong. The spikes usually



FIG. 68.—Outline map of the western United States, showing the distribution of club wheats in 1919. Estimated area, 1,020,300 acres.

are awnless but may be awned, are oblong or sometimes clavate or "club shaped," short, usually less than $2\frac{1}{2}$ inches in length, very compact, and laterally compressed. The spikelets usually contain five fertile florets and spread at nearly a right angle to the rachis. The glumes and lemmas are persistent, so the grain does not shatter when ripe. The kernels of club wheat are small, laterally compressed or "pinched," because of crowding in the compact spikes. Most club-wheat kernels have a small, short

brush and a narrow, very shallow crease. The grain usually is of rather poor quality for bread making.

The club wheats are distinguished from common wheats by the smaller, shorter, denser, laterally compressed spikes. The varieties of wheat grown in the eastern United States often referred to as club because of having clavate spikes do not belong to this species, but are common wheats.

The nonshattering and stiff-strawed characters of club wheats are of much economic importance in the Pacific Coast area, where they are principally grown, because in that area wheat commonly is cut and thrashed in one operation with a combined harvester long after the grain is fully ripe. Figure 68 shows the distribution of club wheats in the United States in 1919.

KEY TO THE VARIETIES OF CLUB WHEAT.

1a. SPIKE AWNLESS.		
2a. GLUMES GLABROUS.		
3a. GLUMES WHITE.		
4a. KERNELS WHITE (<i>Triticum compactum humboldtii</i> Kcke.).		
KERNELS SHORT TO MIDLONG.		
KERNELS SOFT TO SEMIHARD.		Page.
WINTER HABIT.....	HYBRID 128.....	173
SPRING HABIT.		
Plant tall.		
Spike oblong-fusiform.....	LITTLE CLUB.....	174
Spike clavate.....	BIG CLUB.....	175
Plant short; glumes and kernels very short.		
Spike elliptical.....	HYBRID 143.....	176
KERNELS SEMIHARD TO HARD.		
WINTER HABIT.		
Spike oblong-fusiform.....	HYBRID 60.....	176
SPRING HABIT.		
Spike elliptical.....	HYBRID 63.....	176
4b. KERNELS RED (<i>T. c. wernerianum</i> Kcke.)		
KERNELS SHORT TO MIDLONG.		
KERNELS SOFT TO SEMIHARD.		
SPRING HABIT.		
Kernels soft.....	HYBRID 108.....	177
Kernels semihard.....	HYBRID 123.....	177
3b. GLUMES BROWN.		
4a. KERNELS WHITE (<i>T. c. rufulum</i> Kcke.).		
KERNELS SHORT TO MIDLONG.		
KERNELS SOFT TO SEMIHARD.		
SPRING HABIT.		
Spike oblong-fusiform; glumes dark brown.		
Plant tall, late.....	JENKIN.....	178
Spike clavate.		
Glumes light brown.....	REDCHAFF.....	178
Glumes bluish brown.....	BLUECHAFF.....	178
4b. KERNELS RED (<i>T. c. cretium</i> Al.).		
KERNELS SHORT TO MIDLONG.		
KERNELS SOFT TO SEMIHARD.		
SPRING HABIT.		
Spike elliptical, stem purple.....	DALE.....	179
2b. GLUMES PUBESCENT.		
3a. GLUMES WHITE.		
4a. KERNELS RED (<i>T. c. wittmackianum</i> Kcke.).		
KERNELS SHORT TO MIDLONG.		
KERNELS SOFT TO SEMIHARD.		
WINTER HABIT; spike elliptical.....	COPPEI.....	179
3b. GLUMES BROWN.		
4b. KERNELS WHITE.		
KERNELS SHORT TO MIDLONG.		
KERNELS SOFT TO SEMIHARD.		
SPRING HABIT.		
Plant short, early.....	WILBUR.....	180
1b. SPIKE AWNED.		
2a. GLUMES GLABROUS.		
3a. GLUMES BROWN.		
4a. KERNELS RED (<i>T. c. erinaceum</i> Kcke.).		
KERNELS SHORT TO MIDLONG.		
KERNELS SOFT TO SEMIHARD.		
SPRING HABIT.....	MAYVIEW.....	180

DESCRIPTION, HISTORY, DISTRIBUTION, AND SYNONYMY OF CLUB WHEAT VARIETIES.

HYBRID 128.

Description.—Plant winter habit, midseason, midtall; stem white, strong, stout; spike awnless, elliptical, dense, erect; glumes glabrous, white, short, wide; shoulders narrow, usually rounding; beaks wide, obtuse, 0.5 mm. long; apical

awns few, 2 to 10 mm. long; kernels white, short, soft, ovate to oval, irregular, humped; germ mid-sized, abrupt; crease midwide, shallow; cheeks angular; brush small, midlong.

This variety differs from Hybrid 60 in having shorter glumes. It is a true winter wheat, high yielding, but very susceptible to bunt or stinking smut.

Spikes, glumes, and kernels of Hybrid 128 wheat are shown in Plate XLIX, A, and a single spike in Plate V, Figure 7.

History.—Hybrid 128 was originated at Washington Agricultural Experiment Station, Pullman, Wash. Its history has been recorded by Schafer and Gaines (170, p. 8) as follows:

Hybrid No. 128 is a cross between Jones Winter Fife and Little Club. It was originated in 1899 by Prof. W. J. Spillman. After being selected and tested for eight years it was distributed to ranchers for further testing.

Prof. Spillman started his work in wheat breeding at the Washington Agricultural Experiment Station in 1899. Valuable results were obtained, Hybrid 128 being only one of the varieties which resulted from the first crosses. The work was hardly commenced, however, before he left the institution, and the important task of making the selections, testing the many strains, and distributing the new varieties was left to other workers. His work with wheat, however, resulted in some of the very earliest discoveries of the fundamental principles of heredity in plant breeding. He left Pullman in June, 1902, and it was not until 1909 that he published the results of his studies in hybridization (182). In the same year he published a more popular bulletin from the Washington Agricultural Experiment Station, which gave some of the results of his early experiments (183).



FIG. 69.—Outline map of a portion of the Pacific Northwest, showing the distribution of Hybrid 128 wheat in 1919. Estimated area, 259,900 acres.

The wheat breeding was continued at Pullman by Messrs. E. E. Elliott and Claude W. Lawrence (86), who were largely responsible for the distribution of some of the earlier hybrid varieties, including Hybrid 128. The work is still being continued and is now (1921)

in charge of Prof. E. G. Schafer, agronomist, and Prof. E. F. Gaines, cerealist.

Distribution.—Grown in Latah County, Idaho, 11 counties in eastern Washington and in Umatilla County, Oreg. It is the most widely grown club wheat in Washington. (Fig. 69.)

Synonyms.—Washington Hybrid No. 128, White Hybrid. The name White Hybrid is quite widely used for Hybrid 128 as well as the other white-kerneled hybrid wheats distributed by the Washington station.

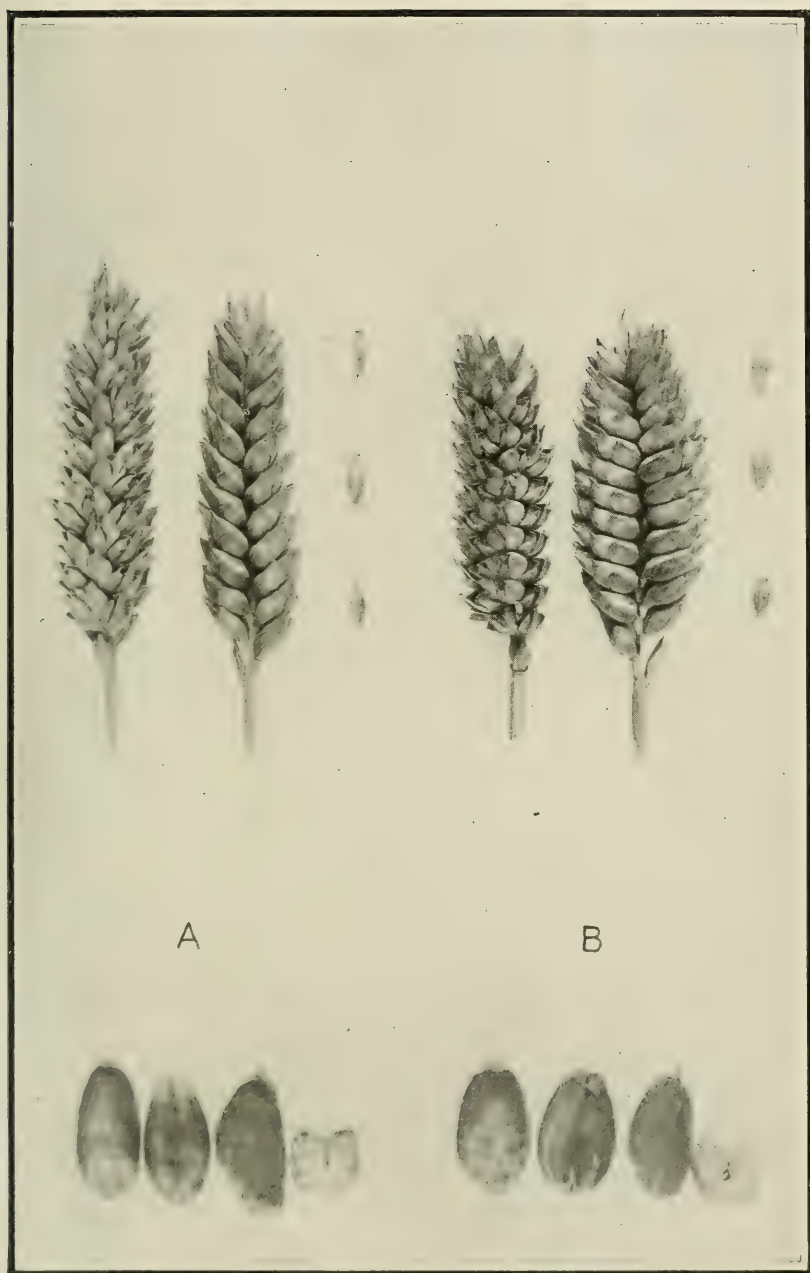
LITTLE CLUB.

Description.—Plant spring habit, midseason, midtall to tall; stem white, strong, stout; spike awnless, oblong-fusiform, dense, erect; glumes glabrous, white, midlong, midwide; shoulders midwide, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 10 mm. long; kernels white, short, soft, ovate, humped, acute; germ small; crease narrow, shallow; cheeks angular to rounded; brush small, midlong.

Little Club is distinguished from other white-glumed club varieties in having longer and more slender spikes and slender, pointed kernels.

Spikes, glumes, and kernels of Little Club wheat are shown in Plate L, A.

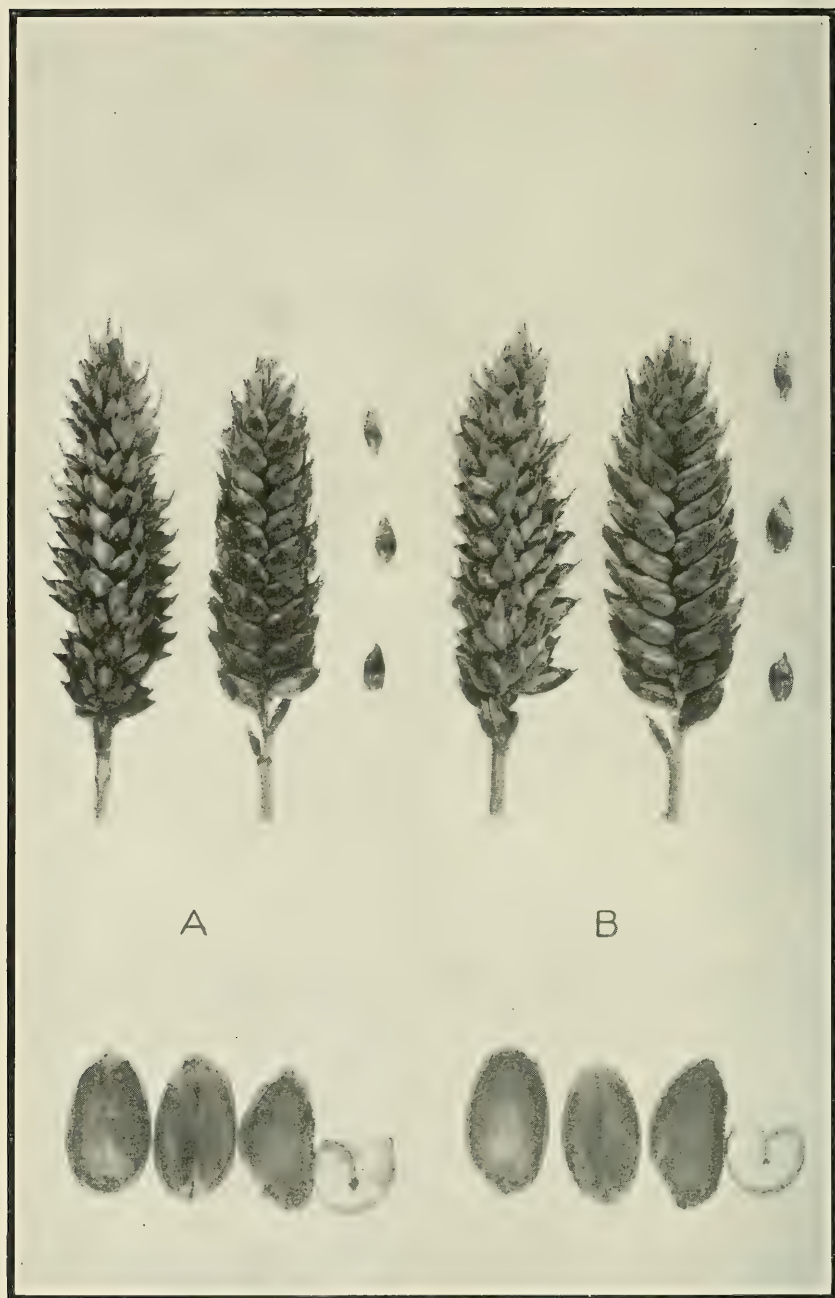
History.—The origin of Little Club wheat is undetermined, but it is believed to have been introduced from Chile, as considerable quantities of club wheats were shipped to the Pacific Coast from Chile during the sixties and seventies.



LITTLE CLUB (A).

BIG CLUB (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



JENKIN (A).

REDCHAFF (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

It was reported grown in Yolo County, Calif., in 1878 (53, p. 339). According to Byron Hunter (124, p. 24), Little Club was probably one of the first varieties of wheat grown in the Columbia Basin of Oregon. For years it was the leading wheat in the Palouse district and continues to be a leading wheat grown along the foothills of the Blue Mountains in Oregon. In this section it often is fall sown, as it usually will stand the winters, though not as well as true winter varieties. It is now less extensively grown than formerly because of the introduction of more suitable varieties.

Distribution.—Little Club is grown in Arizona, California, Idaho, Montana, Nevada, Oregon, Utah, and Washington. (Fig. 70.)

Synonym.—Small Club.

BIG CLUB.

Description.—Plant spring habit, midseason, mid-tall to tall; stem white, curved, strong, stout; spike awnless, elliptical to clavate, dense, erect; glumes glabrous, white, midlong, midwide; shoulders midwide, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 5 mm. long; kernels white, short, soft, nearly oval; humped; germ small; crease narrow, shallow; cheeks usually angular; brush small, midlong.

Big Club differs from Little Club in having wider, shorter, and thicker spikes, in having curved peduncles, and wider and rounder kernels. The shape of the spike is very similar to that of Hybrid 128. Spikes, glumes, and kernels of Big Club wheat are shown in Plate L, B.

History.—Big Club wheat is reported to have been introduced into Oregon about 1870 from Chile (10). The variety was first known as Chile Club and Oregon Club. It was evidently first grown in California, for in 1866 Chile Club was reported to be "remarkably well adapted to the soil and climate" of that State (84, p. 586).

The name Big Club has been used for the variety only during the last 10 to 15 years, and it probably came into use to distinguish it from Little Club.

Distribution.—Big Club is grown in California, Idaho, Montana, Oregon, Utah, and Washington. (Fig. 71.)

Synonyms.—Big Four, Chile Club, Crookneck Club, Montezuma Club, Oregon Club, Salt Lake Club. Big Four is a name under which Big Club wheat is known in the State of Idaho. Chile Club is the name under which this wheat was first grown in the United States. It has become best known under this name in California. Crookneck Club is the name which became applied to Big Club wheat because of the distinct crooks or curves which usually occur in the upper portion of

the peduncle. Montezuma Club is a name for Big Club wheat in California. Oregon Club is a name which was early used for Big Club in the State of Oregon. It was widely known by that name in the seventies. Salt Lake Club is a name which became used for Big Club wheat in the State of Utah. How and when the name originated is not known.

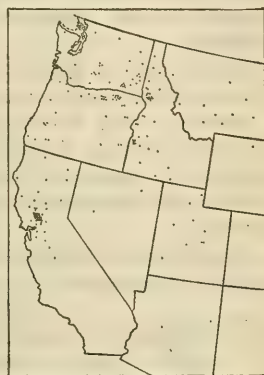


FIG. 70.—Outline map of the western United States, showing the distribution of Little Club wheat in 1919. Estimated area, 106,100 acres.



FIG. 71.—Outline map of the Pacific and Basin areas, showing the distribution of Big Club wheat in 1919. Estimated area, 21,700 acres.

HYBRID 143.

Description.—Plant intermediate to spring habit, midseason to late, midtall; stem white, strong; spike awnless, elliptical, dense, erect; glumes glabrous, white, short, wide; shoulders midwide, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 10 mm. long; kernels white, very short, soft, ovate to oval to oblong, humped; germ small to midsized, abrupt; crease narrow, shallow; cheeks angular; brush very small, short to midlong.

Hybrid 143 is distinct in having very short kernels. Spikes, glumes, and kernels of this variety are shown in Plate XLIX, B.

History.—This wheat was originated at the Washington Agricultural Experiment Station, Pullman, Wash., from a cross between White Track and Little Club, made by Prof. W. J. Spillman in 1899. It was first distributed in 1907 by the Washington station and has been grown both from fall or spring sowing.

Distribution.—Hybrid 143 was reported in 1919 from seven counties in eastern Washington. It was reported grown most extensively in Columbia County, where it made up 15 per cent of the total wheat of the county. (Fig. 72.)



FIG. 72. — Outline map of a portion of the Pacific Northwest, showing the distribution of Hybrid 143 wheat in 1919. Estimated area, 49,500 acres.

Synonyms.—Shot Club, White Hybrid. The name Shot Club is sometimes used for Hybrid 143 by men in the grain trade because of its peculiar short, roundish, shotlike kernels.

HYBRID 60.

Description.—Plant winter habit, midseason, short to midtall; stem white, strong; spike awnless, elliptical, dense, erect; glumes glabrous, white, midlong, narrow; shoulders narrow, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 5 to 30 mm. long; kernels white, short, hard, ovate, humped; germ small; crease narrow, shallow; cheeks usually angular; brush small, short to midlong.

History.—This variety originated at the Washington Agricultural Experiment Station from a cross between Turkey and Little Club made by Prof. W. J. Spillman, at Pullman, Wash., in 1899. It was increased and was distributed in 1905 from the Washington station by E. E. Elliott.

Distribution.—Grown in experiments at field stations in the Pacific Northwest. It is not now known to be commercially grown.

HYBRID 63.

Description.—Plant spring habit, midseason, midtall; stem white, strong; spike awnless, elliptical to oblong, dense, erect; glumes glabrous, white, midlong, narrow to midwide; shoulders midwide, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 5 mm. long; kernels white, short, semihard to hard, ovate to elliptical, humped; germ small; crease narrow, shallow; cheeks rounded to angular; brush small, midlong.

This variety is distinguished by its short spike and rather long, narrow glumes.

History.—This wheat was originated at the Washington Agricultural Experiment Station, Pullman, Wash. It is of hybrid origin, being one of the results of crosses made by Prof. W. J. Spillman in 1899 between Turkey and Little Club, in an effort to produce a club wheat with a true winter habit. This variety was distributed to farmers in 1907 by the Washington station. Although it is a true spring wheat, it has usually been grown from fall sowing and proved to be a good yielder under a rainfall of 15 to 18 inches.

Distribution.—Grown in Jackson, Umatilla, and Wasco Counties, Oreg., and Columbia, Franklin, Garfield, Kittitas, and Walla Walla Counties, Wash. It is most important in Walla Walla County, Wash.

Synonym.—White Hybrid.

HYBRID 108.

Description.—Plant intermediate to spring habit, midseason, midtall; stem white, strong; spike awnless, elliptical, dense, erect; glumes glabrous, white, midlong, midwide; shoulders midwide, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 5 mm. long; kernels red, usually short, soft, oval to elliptical, humped, pinched; germ small; crease narrow, shallow; cheeks angular; brush small, midlong.

History.—This variety was originated at the Washington Agricultural Experiment Station, Pullman, Wash., from a cross between Jones Fife and Little Club, made by Prof. W. J. Spillman in 1899. The variety was distributed by the Washington station in 1907, after the early trials had indicated that it was a good yielding variety. Later experiments, however, did not show favorable results, and because of its poor milling qualities its further distribution was discouraged.

Distribution.—Grown in Whitman County, Wash.

Synonyms.—Red Hybrid and Red Walla. Red Hybrid is a name used to distinguish this variety and Hybrid 123 from the white-kerneled hybrid club varieties previously mentioned. Red Walla is used as a synonym for Hybrid 108 and Hybrid 123 because it is the name of the subclass in which all red-kerneled club wheats are graded according to the Federal Grain Standards. The name Red Walla frequently is used for the Red Russian variety as well as the club wheats.

HYBRID 123.

Description.—Plant spring habit, midseason to late, midtall; stem white, strong; spike awnless, oblong to elliptical, dense, erect; glumes glabrous, white, short, midwide; shoulders narrow, usually rounded; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 5 mm. long; kernels red, small, soft to semi-hard, ovate, humped; germ small; crease midwide, shallow; cheeks angular; brush small, midlong.

Hybrid 123 is the only important red-kerneled variety of club wheat in the United States. It is distinguished from Hybrid 108 by having slightly harder kernels.

History.—The history of Hybrid 123 is the same as that stated for Hybrid 108. This variety, however, became much more popular than No. 108.

Distribution.—Hybrid 123 was reported in 1919 from Sherman County, Oreg., and six counties in Washington, being grown most extensively in Klickitat County.

Synonyms.—Red Hybrid and Red Walla. These names are discussed under Hybrid 108.

JENKIN (JENKIN'S CLUB).

Description.—Plant spring habit, late, tall; stem white, strong; spike awnless, oblong-fusiform, dense, erect; glumes glabrous, brown, midlong, midwide; shoulders midwide, usually rounded; beaks broad, obtuse, 0.5 mm. long, apical awns few, 2 to 10 mm. long; kernels white, small, soft, broadly ovate, humped; germ small, abrupt; crease midwide, middeep to deep, sometimes pitted; cheeks angular to rounded; brush small, midlong.



FIG. 73.—Outline map of a portion of the Pacific Northwest, showing the distribution of Jenkin wheat in 1919. Estimated area, 66,500 acres.

This is the tallest commercial variety of club wheat and is taller than most common wheats grown. Spikes, glumes, and kernels of Jenkin are shown in Plate LI, A.

History.—The origin of Jenkin wheat is undetermined. It is known to have been grown in the vicinity of Wilbur, Lincoln County, Wash., about 1895' (125). By 1900 it became grown around Walla Walla, Wash., and Pendleton, Oreg., and during the next decade largely replaced other varieties in those sections, being grown from both fall and spring sowing.

Distribution.—Grown in Idaho, Oregon, and Washington. (Fig. 73.)

REDCHAFF (RED CHAFF CLUB).

Description.—Plant spring habit, midseason, midtall; stem white, strong; spike awnless, clavate, dense, erect; glumes glabrous, light brown, midlong, midwide; shoulders midwide, usually oblique; beaks wide, obtuse, 0.5 mm. long; apical awns few, 2 to 10 mm. long; kernels white, short, soft, ovate, humped; germ small, abrupt; crease midwide, shallow; cheeks usually angular; brush small, midlong.

Redchaff differs from Jenkin in being shorter, earlier, in having a more clavate spike and lighter brown glumes. Spikes, glumes, and kernels of Redchaff are shown in Plate LI, B.

History.—The origin of Redchaff is undetermined. According to Hunter (124, p. 24), it was an important variety of club wheat grown in the Columbia Basin of Oregon and Washington in 1907.

Distribution.—Grown in Idaho, Oregon, and Washington. (Fig. 74.)

Synonyms.—Oregon Red Chaff and Red Chaff Club. The name Oregon Red Chaff sometimes is used for the Redchaff variety, but is more commonly applied to Foisy. Red Chaff Club is the name used by most growers of the variety.

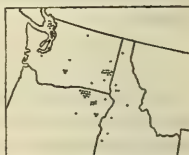


FIG. 74.—Outline map of a portion of the Pacific Northwest, showing the distribution of Redchaff wheat in 1919. Estimated area, 40,000 acres.

BLUECHAFF (BLUE CHAFF CALVERT CLUB).

Description.—Plant intermediate to spring habit, late, midtall; stem white, strong; spike awnless, clavate, dense, erect; glumes glabrous, bluish brown, midlong, midwide; shoulders wanting to narrow, usually rounded; beaks narrow, incurved, obtuse, 0.5 to 1 mm. long; apical awns few, 2 to 20 mm. long; kernels white, short to midlong, soft, ovate, humped; germ small; crease midwide, shallow; cheeks angular; brush small, midlong.

The glumes of Bluechaff have a distinct bluish tinge not observed in any other club wheats. Spikes, glumes, and kernels of this variety are shown in Plate LII, A.

History.—The origin of Bluechaff (Blue Chaff Calvert Club) was recorded,²⁹ by James Calvert, of Junction City, Oreg., as follows:

My boy, A. C. Calvert, while shocking after me while I was binding. 24 years ago this harvest, found seven heads of the wheat from one stalk. It looked so much better, harder, and plumper wheat than any of the other wheat, that I took it home and planted it in the garden and hoed it the same as we did the corn, and it developed such plump heads and kernels of wheat that I kept on until the seventh year, when we raised 750 bushels of wheat.

Distribution.—Reported in 1919 from Jackson County, Oreg. It is known to be or to have been grown in Benton, Linn, and Lane Counties, Oreg.

DALE (DALE GLORIA).

Description.—Plant spring habit, midseason, short to midtall; stem purple, strong, stout; spike awnless, elliptical, dense, erect; glumes glabrous, dark brown, midlong, midwide; shoulders wanting to narrow, oblique; beaks wide, obtuse, 0.5 mm. long; apical awns several, 3 to 20 mm. long; kernels red, short to midlong, soft, ovate, humped, pinched; germ small; crease narrow, shallow; cheeks rounded to angular; brush small, midlong.

This variety is distinguished by its red kernels and purple straw. Dale (Dale Gloria), as commercially grown, usually is a mixture, the type described above predominating. White-kerneled strains, having both white and brown glumes, have been obtained from commercial fields. Spikes, glumes, and kernels of this variety are shown in Plate LII, B.

History.—The origin of Dale (Dale Gloria) wheat has been recorded by Hunter (125), as follows:

During the year 1900 Mr. William H. Dale, of Helix, Umatilla County, Oreg., found a stool of wheat of eight heads growing among his other wheat. He recognized the superior qualities of this individual plant, saved the seed, and planted it by itself. The next year, 1901, he raised 4 pounds of seed. In 1902 he raised 5 bushels, in 1903 there were 51 sacks, and in 1904, 4,000 bushels. Knowing no name for the variety he called it Dale Gloria.

Distribution.—Grown in Umatilla County, Oreg., and Whitman County, Wash.

COPPEI.

Description.—Plant winter habit, midseason, midtall; stem white, strong; spike awnless, oblong to elliptical, dense, erect; glumes pubescent, white, midlong, midwide; shoulders narrow, usually oblique; beaks wide, obtuse, 0.5 to 1 mm. long; apical awns several, 2 to 15 mm. long; kernels red, short to midlong, soft to semihard, ovate, humped; germ midsized; crease midwide, middeep; cheeks rounded to angular; brush small, midlong. (Pl. LIII, A.)

History.—Coppei was developed by J. L. Harper, who, in the fall of 1907, selected a plant of an unknown variety found in a field of Little Club belonging to W. G. Preston, located near Coppei Creek, 3 miles south of Waitsburg, Wash. Mr. Harper saved five heads from this plant and sowed the seed from them in his garden in Waitsburg. In 1908 he thrashed from this plat about a pound of wheat. This he gave to J. B. Kinder, a farmer, who increased the seed until 1911, when he distributed it to others. Mr. Harper named the variety Coppei because it came from a farm near Coppei Creek.³⁰ The variety is probably the result of a natural field cross between Little Club and Jones Fife.

²⁹ Correspondence with Ira P. Whitney, county agricultural agent, Eugene, Oreg., dated Oct. 17, 1921.

³⁰ Correspondence from Prof. R. K. Bonnett, Idaho Agricultural Experiment Station, dated July 24, 1920.

Distribution.—Coppei was reported in 1919 from Columbia and Whitman Counties, Wash.

WILBUR (EARLY WILBUR).

Description.—Plant spring habit, early, short; stem white, strong; spike awnless, oblong, dense, erect; glumes pubescent, brown, short, midwide; apical awns many, 1 to 3 cm. long; kernels white, midsized, soft.

History.—The origin of Early Wilbur was recorded by Hunter (125) in 1909 to be as follows:

Some 10 or 12 years ago Mr. W. J. Mariner, of Blalock, Oreg., was at Wilbur, Wash., where he found the farmers growing Jenkin's Club. He was pleased with the wheat and shipped a carload home for seed. In growing the Jenkins he noticed stools of another variety growing here and there that were earlier and filled better than the Jenkins. Seed of this early variety was gathered and grown separately until 2,500 bushels were on hand, when it was sold at \$1 per bushel for seed. Each year the plat was carefully looked over and individual plants not true to type were discarded. Because of its earliness and because the wheat was found in seed that came from Wilbur, Wash., Mr. Mariner called it Early Wilbur. Considerable of this wheat is now grown in Sherman and Gilliam Counties, in Oregon, as well as other localities.

Distribution.—Reported in 1919 from Gilliam, Jefferson, and Sherman Counties, Oreg.

MAYVIEW.

Description.—Plant spring habit, late, midtall; stem usually white, sometimes faintly purple on lower internodes; spike awned, elliptical to clavate, dense, erect; glumes glabrous, brown, midlong, wide; shoulders midwide, usually rounded; beaks wide, incurved, 1 to 4 mm. long; awns 2 to 5 cm. long; kernels red, short, soft, ovate, humped, curved; germ small; crease midwide, shallow; cheeks usually angular; brush small, short.

This variety is distinguished by the awned spikes. (Pl. LIII, B.)

History.—This wheat was found growing in the summer of 1917 in the vicinity of May View, Wash., by Prof. E. F. Gaines, of the Washington Agricultural Experiment Station, who named the variety Mayview. It originated from a selection of an admixture in a field of Fortyfold in 1911 or 1912. Several thousand bushels were said to have been grown around May View, Wash., by 1915. Its culture has since been largely discontinued on account of its awns.

Distribution.—Mayview was not reported in the survey of 1919, but samples of the variety have been received for identification from Garfield County, Wash., Adams County, Oreg., and Fergus County, Mont.

POULARD WHEAT.

The poulard wheats usually are tall, with broad leaves. The culms are thick, usually solid, but sometimes pithy. The spikes are long and occasionally compound or branched. The spikelets are compactly arranged on the spike and the glumes are short and sharply keeled. The kernels are thick, humped, and mostly hard, but usually become very starchy (yellow berry).

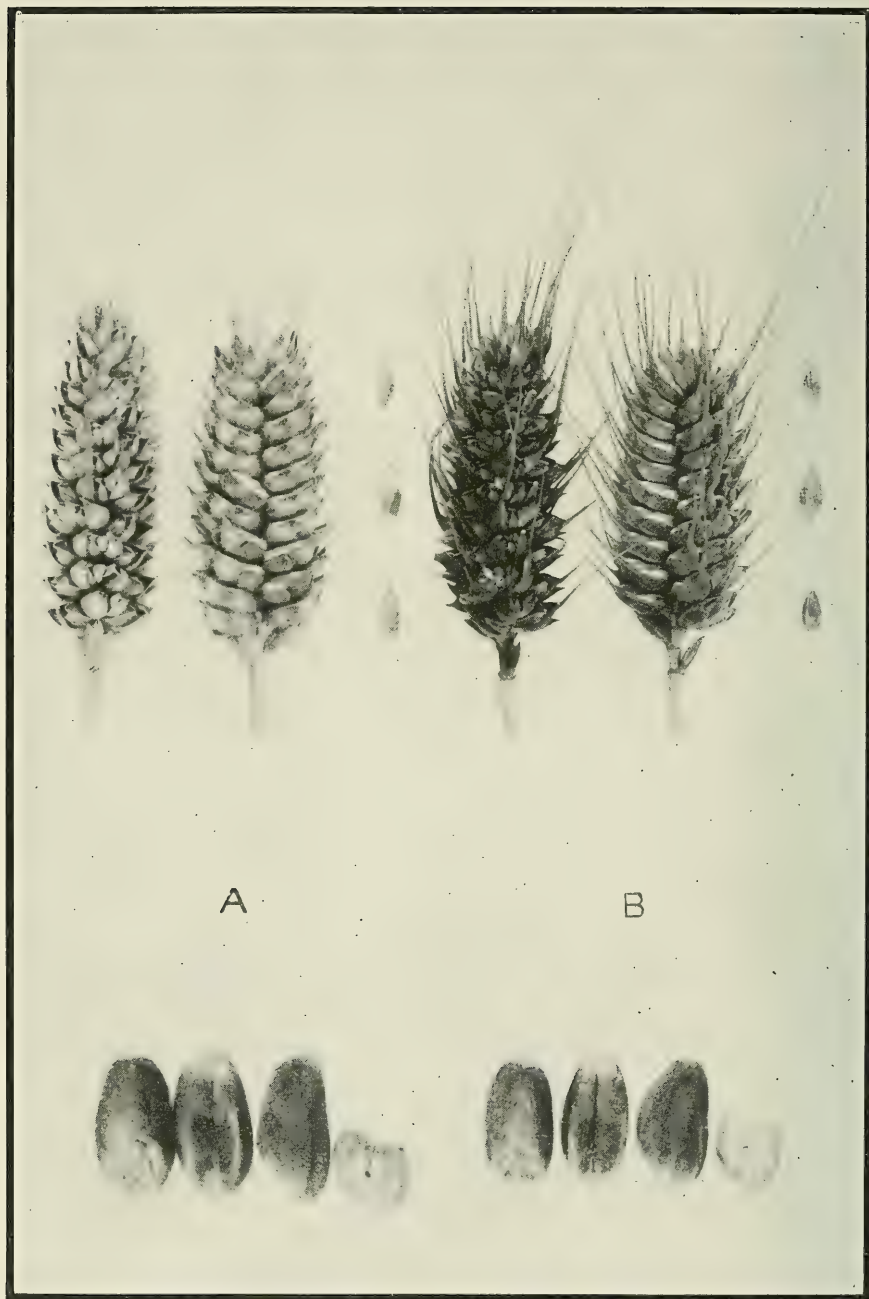
The poulards are most closely related to the durumms. The glumes and kernels usually are shorter and the kernels thicker in the dorso-



BLUECHAFF (A).

DALE (B).

Spike, face and side views, natural size; plumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



COPPEI (A).

MAYVIEW (B).

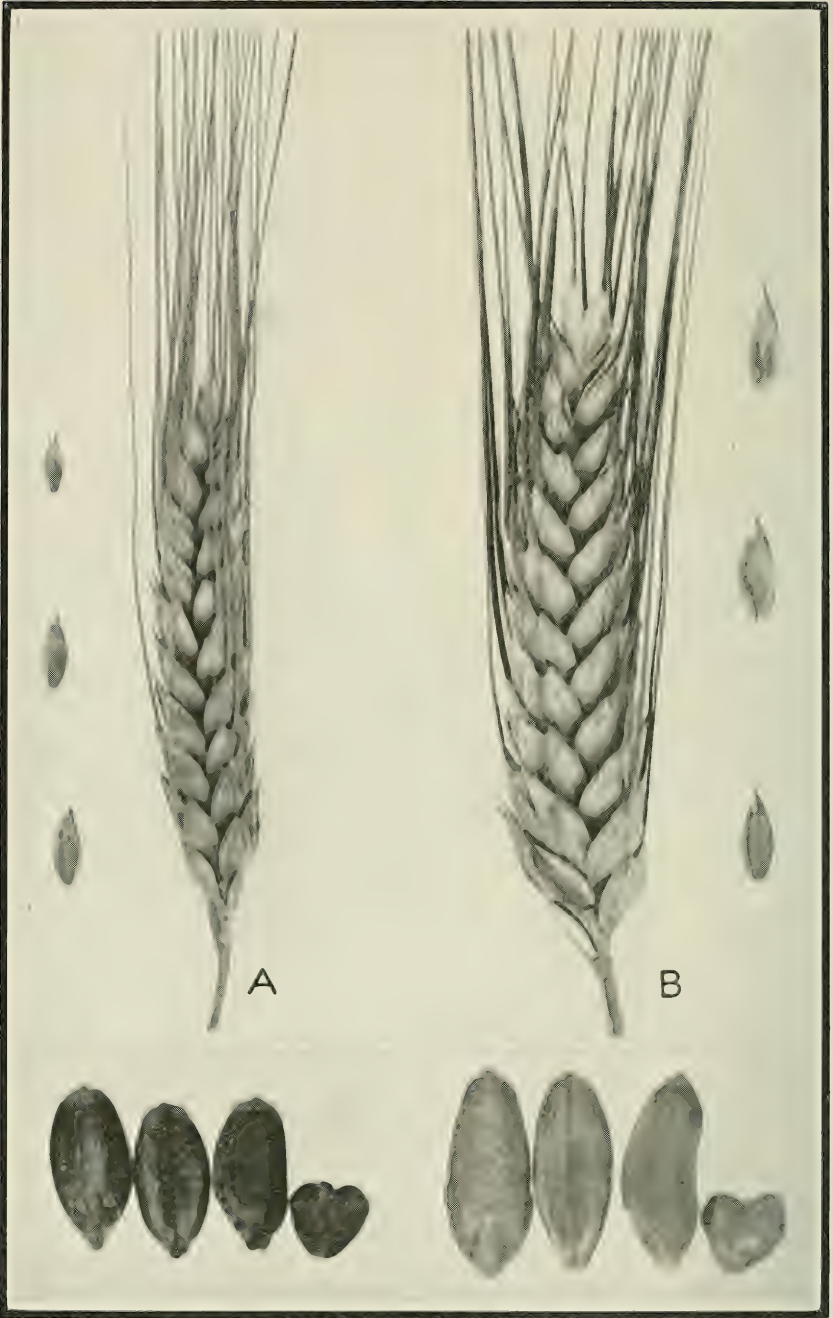
Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



ALASKA (A).

TITANIC (B).

Spike, side view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



PENTAD (A).

PELISS (B).

Spike, side view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

ventral diameter and are somewhat softer. In many instances the varieties of poulard and durum are so near alike that it is difficult to distinguish them.

Only a few varieties of poulard wheat are cultivated in the United States, and the grain of these is of no commercial value except as feed for stock. The varieties grown can be distinguished by the accompanying key.

KEY TO THE VARIETIES OF POULARD WHEAT.

1a. SPIKE SIMPLE.		
2a. SPIKE AWNED.		
3a. GLUMES PUBESCENT.		
4a. GLUMES WHITE.		
5a. KERNELS RED (<i>Triticum turgidum jodurum</i> Al.).		
KERNELS SHORT TO MIDLONG.		Page.
* SPRING HABIT.....	CLACKAMAS.....	181
1b. SPIKE BRANCHED.		
2a. SPIKE AWNED.		
3a. GLUMES GLABROUS.		
4a. GLUMES WHITE.		
5a. KERNELS WHITE		
KERNELS SHORT TO MIDLONG.		
SPRING HABIT.....	ALASKA.....	182
3b. GLUMES PUBESCENT.		
4a. GLUMES BROWN.		
5a. KERNELS WHITE (<i>T. t. mirabile</i> Kcke.).		
KERNELS MIDLONG TO LONG.		
WINTER HABIT.....	TITANIC.....	182
5b. KERNELS RED (<i>T. t. linnaeanum</i> Al.).		
KERNELS SHORT TO MIDLONG.		
WINTER HABIT.....	WINTER ALASKA.....	183

DESCRIPTIONS, HISTORY, DISTRIBUTION, AND SYNONYMY OF POULARD WHEAT VARIETIES.

CLACKAMAS (CLACKAMAS WONDER).

Description.—Plant spring habit, late, tall; leaves pubescent; stem white, weak to midstrong; spike simple, awned, oblong, middense, nodding; glumes glabrous with pubescent edges, white with bluish black edges, midlong, midwide; shoulders narrow, oblique to elevated; beaks wide, 1 to 2 mm. long; awns black, 5 to 18 cm. long; kernels red, midlong to long, hard, usually becoming starchy, broadly ovate, truncate at tip; crease midwide, shallow; cheeks angular; brush mid-sized, short.

Clackamas differs from other varieties of poulard wheat grown in the United States in having simple spikes. It differs from the old Rivet wheat of England in having a spring habit and partly glabrous glumes. As grown commercially, Clackamas is somewhat mixed with common wheat and also contains several other types of simple-spiked poulard wheat.

History.—The origin of this variety is not known. Seed of the strain above described was obtained in 1918 from New Mexico, where it has been grown to a considerable extent for several years, apparently without a name. A wheat which apparently is identical with the above has been grown in Clackamas County, Oreg., for several years under the name Clackamas Wonder.

Distribution.—Grown in New Mexico and Oregon.

ALASKA.

Description.—Plant spring habit, late, tall; stem white, midstrong, spike branched, awned, nodding; glumes glabrous, brown, short, midwide; shoulders narrow, usually rounded; beaks nearly wanting; awns black, 3 to 12 cm. long; kernels white, short to midlong, hard, often becoming starchy, ovate, humped; germ mid-sized; crease midwide, shallow, sometimes pitted; cheeks usually angular; brush mid-sized, short.

Alaska is recognized by the composite spikes, glabrous glumes, and white kernels. A spike, glumes, and kernels of this variety are shown in Plate LIV, A.

History.—This variety of poulard wheat probably has been introduced into this country several times from the Mediterranean region of Europe, where poulard wheats are grown commercially to a small extent. The first introduction of this wheat into the United States was thought by Ball and Leighty (44 p. 4) to have been in 1806, when it was brought from Ireland under the name of Jerusalem. Several other introductions have been recorded in American literature. The wheat often has been used by unscrupulous seedsmen for extravagant exploitation. The names listed as synonyms have all been used at one time or another for the variety in the United States. In recent years the name Alaska has been generally adopted for the wheat. It was the name used for the variety by Abraham Adams, of Juliaetta, Idaho, who distributed seed of the variety in the Pacific Northwest from about 1904 to 1908.

Distribution.—Alaska wheat was reported in 1919 from Arizona, New Mexico, Oregon and Pennsylvania. It also is known to be grown to a small extent in California, North Dakota, Montana, and Idaho.

Synonyms.—Egyptian, Eldorado, Jerusalem, Many Headed, Many Spiked, Multiple Headed, Miracle, Mortgage Lifter, Mummy, Reed, Seven Headed, Seven Headed Sinner, Smyrna, Syrian, Taos, Wheat of Miracle, Wheat 3,000 Years Old, Wild Goose.

The names Egyptian, Jerusalem, Mummy, Smyrna, Syrian, and Wheat 3,000 Years Old were applied to this wheat by exploiters who claimed the wheat had been discovered in ancient tombs in Africa or Asia.

The names Many Headed, Many Spiked, Multiple Headed, Seven Headed, and Seven Headed Sinner have been used because of the composite spikes which sometimes produce several branches.

Eldorado, Miracle, Mortgage Lifter, and Wheat of Miracle are names given to the wheat because of its supposed large yields.

Reed is a name used for Alaska because of its tall coarse stem, which is reed-like. Taos is a name long used for Alaska in New Mexico and Utah. Wild Goose is a name given Alaska and several other wheats by men who claimed to have obtained the seed from the crop of a wild goose which had been shot.

TITANIC.

Description.—Plant winter habit, late, midtall to tall; stem white, midstrong, stout; spike branched, awned, nodding; glumes pubescent, brown, short, narrow; shoulders wanting to narrow, oblique; beak 0.5 mm. long; awns black, usually deciduous, 3 to 10 cm. long; kernels white, midlong, semihard, usually becoming very starchy, oval to ovate, humped; germ mid-sized; crease midwide, shallow, sometimes pitted; cheeks angular; brush mid-sized, short.

This variety differs from Alaska in having a winter habit and pubescent brown glumes. A spike, glumes, and kernels are shown in Plate LIV, B.

History.—The Titanic wheat was introduced into the United States by Harry Towell, of Fort Stanley, Wash., in 1912. Mr. Towell had obtained 12 kernels

from a friend in England, who had obtained a very small quantity from an importation made into that country from Argentina. The wheat was first grown on the San Juan Islands, in Washington, by Mr. Towell, and by 1916 he had about 100 acres. J. C. Hawkins, then a student at the Oregon Agricultural College, contracted to sell the wheat in 1916 for seed at \$1 a pound. He gave it the name Titanic, because of the marine disaster which occurred during the year the variety was introduced, Mr. Towell, the introducer, being one of the surviving passengers on the vessel.

Distribution.—Grown to a very small extent in the Puget Sound section of Washington.

WINTER ALASKA.

Description.—Plant winter habit, late, midtall; stem white, midstrong, stout; spike branched, awned, nodding; glumes pubescent, brown, short, narrow; shoulders narrow, usually oblique; beaks 1 to 2 mm. long; awns black, usually deciduous; awns 3 to 10 cm. long; kernels red, small to midsized, hard, often becoming starchy, ovate; germ midsized; crease midwide, shallow; cheeks angular; brush midsized, short.

This variety differs from Titanic in having red kernels.

History.—Winter Alaska was obtained from the Washington Agricultural Experiment Station, Pullman, Wash., in 1917. It was grown by that station for several years previous, but its previous history could not be traced.

Distribution.—Grown in experiments at experiment stations in Washington and commercially to a small extent in the vicinity of Puyallup, Pierce County, Wash.

DURUM WHEAT.

The plants of durum wheat usually are of spring habit and tall. The peduncle is pithy, at least in the upper portion. The spikes are compact and laterally compressed, and hence are narrower when seen in a face view. The glumes are persistent, sharply keeled, and the lemmas always awned except in a few awnless forms recently originated by hybridization. The awns are long and coarse and are white, yellow, brown, or black. The kernels are white or red and usually rather long and pointed; they are very hard and translucent, making the white-kerneled forms appear amber-colored. The kernels always have a short brush and angular cheeks and are the hardest of all known wheats.

The durum wheats, as before stated, are sometimes very similar to certain poulard varieties. The spikes, however, usually are much thinner, the glumes are longer, and the kernels are longer, more slender, and usually much harder.

Durum wheat has been widely grown in the United States only during the past 20 years. Most of the varieties were introduced from southern Russia and the Mediterranean region, where these wheats principally are grown. Certain introductions, including Kubanka, made by the Department of Agriculture about 1900, became popular with farmers in the northern Great Plains and Prairie sections and the production rapidly increased. The distribution of durum wheat

in 1919 is shown in Figure 75. The durumums furnish the great bulk of the world's supply of wheat for the manufacture of semolina, macaroni, and spaghetti. The production of durum wheat in the United

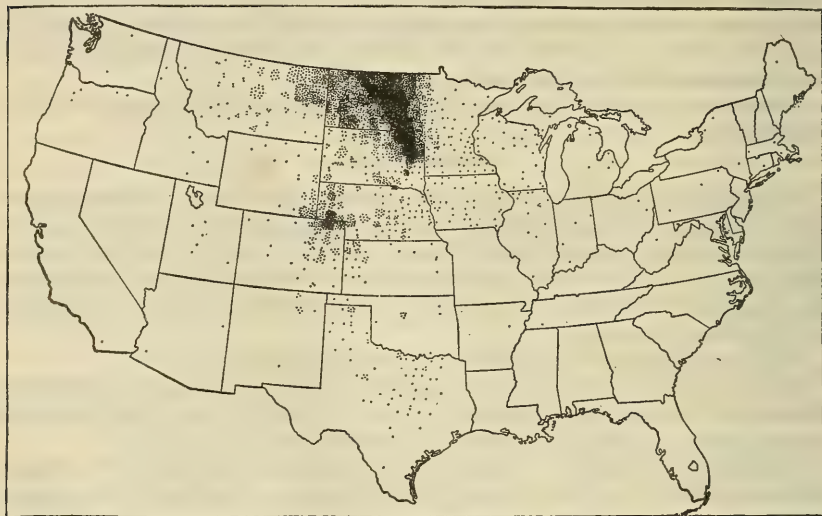


FIG. 75.—Outline map of the United States, showing the distribution of durum wheat in 1919. Estimated area, 4,340,000 acres.

States made possible a large macaroni industry, which now uses about a third of the national production of this wheat. The remainder is exported or used by American mills or bakeries for mixing with other wheats or flour for bread making.

The varieties that are commercially grown are distinguished by the accompanying key.

KEY TO THE VARIETIES OF DURUM WHEAT.

1a. SPIKE AWNED.		
2a. GLUMES GLABROUS.		
3a. GLUMES WHITE.		
4a. AWNS WHITE.		
5a. KERNELS RED (<i>Triticum durum affine</i> Kcke.).	Page.	
KERNELS MIDLONG, HARD.....	PENTAD.....	185
4b. AWNS BLACK.		
5a. KERNELS WHITE (AMBER) (<i>T. d. leucomelan</i> Al.).		
KERNELS VERY LONG, HARD.....	PELISS.....	186
3b. GLUMES YELLOW.		
4a. AWNS WHITE.		
5a. KERNELS WHITE (<i>T. d. hordeiforme</i> Host.).		
KERNELS LONG, HARD.		
Spike fusiform.		
Plant midtall; beaks 1-2 mm. long.....	ACME.....	186
	MONAD.....	187
Plant tall; beaks 1-5 mm. long.....	ARNAUTKA.....	187
	MINDUM.....	188
Spike oblong; plant tall.		
Beaks 1-2 mm. long.....	KUBANKA.....	189
	KUBANKA No. 8.....	190
	BUFORD.....	190
Beaks 1-10 mm. long.....	MAROUANI.....	190

1a. SPIKE AWNED—Continued.

2b. GLUMES PUBESCENT.

3a. GLUMES WHITE.

4a. AWNS BLACK.

5a. KERNELS WHITE (*T. d. melanopus* Al.).

KERNELS LONG, HARD.

Beaks 1-2 mm. long.....	VELVET DON.....	191
Beaks 1-5 mm. long.....	GOLDEN BALL.....	191

3b. GLUMES BLACK.

4a. AWNS BLACK.

5a. KERNELS WHITE (*T. d. taganrogense* Desv.).

KERNELS LONG, HARD.

Beaks 1-2 mm. long.....	KAHLA.....	192
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DESCRIPTIONS, HISTORY, DISTRIBUTION, AND SYNONYMY OF DURUM WHEAT VARIETIES.

PENTAD (D-5).

Description.—Plant spring habit, midseason, midtall; stem white, midstrong; spike awned, fusiform, middense, inclined; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique to elevated; beaks 1 to 2 mm. long; awns white, 5 to 15 cm. long; kernels red, midlong, hard, ovate, truncate tip, humped; germ mid-sized; crease midwide, shallow; cheeks angular; brush mid-sized, short.

The Pentad or D-5 (Durum No. 5) variety is distinct from all other commercial varieties of durum wheat grown in the United States because of its red kernels. They are smaller, squarer at the brush end, and more pointed at the germ end than kernels of the other durum varieties. Experiments have shown it to be the most rust-resistant variety of wheat grown in the United States, and therefore it yields well under conditions favoring rust. Its milling and baking value, however, has been found to be inferior to other durum varieties. A spike, glumes, and kernels of Pentad wheat are shown in Plate LV, A.

History.—The Pentad variety was introduced from Russia in 1903 by Prof. H. L. Bolley, of the North Dakota Agricultural Experiment Station. The wheat was distributed in several sections of North Dakota by Professor Bolley in the spring of 1911. Because of its rust resistance it gained popularity and has recently become widely distributed in the durum-wheat section, but its poor milling quality has caused its distribution to be opposed by many agencies. The name Pentad is derived from penta, meaning five in Greek, plus *d*, which stands for durum. The name was suggested to the North Dakota station by the senior writer in 1917. It has recently been used by Professor Bolley as a name for D-5, and was first recorded by Trowbridge (196, p. 17) in 1920.

Distribution.—Pentad was reported in 1919 from Minnesota, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. It is grown principally in North Dakota.

Synonyms.—"D-five," Ladd Durum, Red Durum, Resistant Five, and Rust Proof.

The name "D-five" is often but wrongly used by many farmers in North Dakota. The practice is easily accounted for, as the numeral 5 has been mispronounced as five. Ladd Durum is a name used in the grain trade for Pentad wheat under the supposition that Dr. E. F. Ladd, formerly of the North Dakota Agricultural College, was the originator. Red Durum is a name commonly used for Pentad wheat, as it is the name of the subclass under which the grain of this wheat is graded under the Official Grain Standards. Resistant Five and Rust Proof are names used for Pentad wheat on the farms, because the variety has proved to be resistant to stem rust.

PELISS (PELISSIER).

Description.—Plant spring habit, midseason, tall; stem white, midstrong; spike awned, broadly fusiform, middense, inclined; glumes glabrous, white, long, wide; shoulders narrow to midwide, oblique to elevated; beaks 1 to 5 mm. long; awns black, 6 to 18 cm. long; kernels white (amber), very long, hard, elliptical, curved, humped; germ mid-sized; crease midwide, middeep; cheeks angular; brush small, short.

Peliss is distinct from Kubanka in having white rather than yellowish glumes, black awns, and very long kernels, which are somewhat curved. It is a high-yielding and drought-resistant variety in the higher and drier sections of Montana and Wyoming. A spike, glumes, and kernels of Peliss are shown in Plate LV, B.

History.—The Peliss (Pelissier) (197, S. P. I. No. 5380) variety was introduced from Mustapha, Algiers, Algeria, by W. T. Swingle, of the United States Department of Agriculture, in 1900. The variety, presumably of Spanish origin, is widely distributed throughout northern Africa, where it is grown under many different names. According to Scofield (172, p. 38) the original seed was obtained from a man named Pelissier, who lived near Ponts des Issers in the western part of the Province of Oran and who did some work in selection to improve the yield of this variety. In the United States the variety was first called Pelissier, but the name was usually mispronounced, so the shorter and simpler form, Peliss, was substituted in 1920 (66, p. 10).

Distribution.—Grown in experiments in the northern Great Plains area and commercially in Montana, North Dakota, and Wyoming.

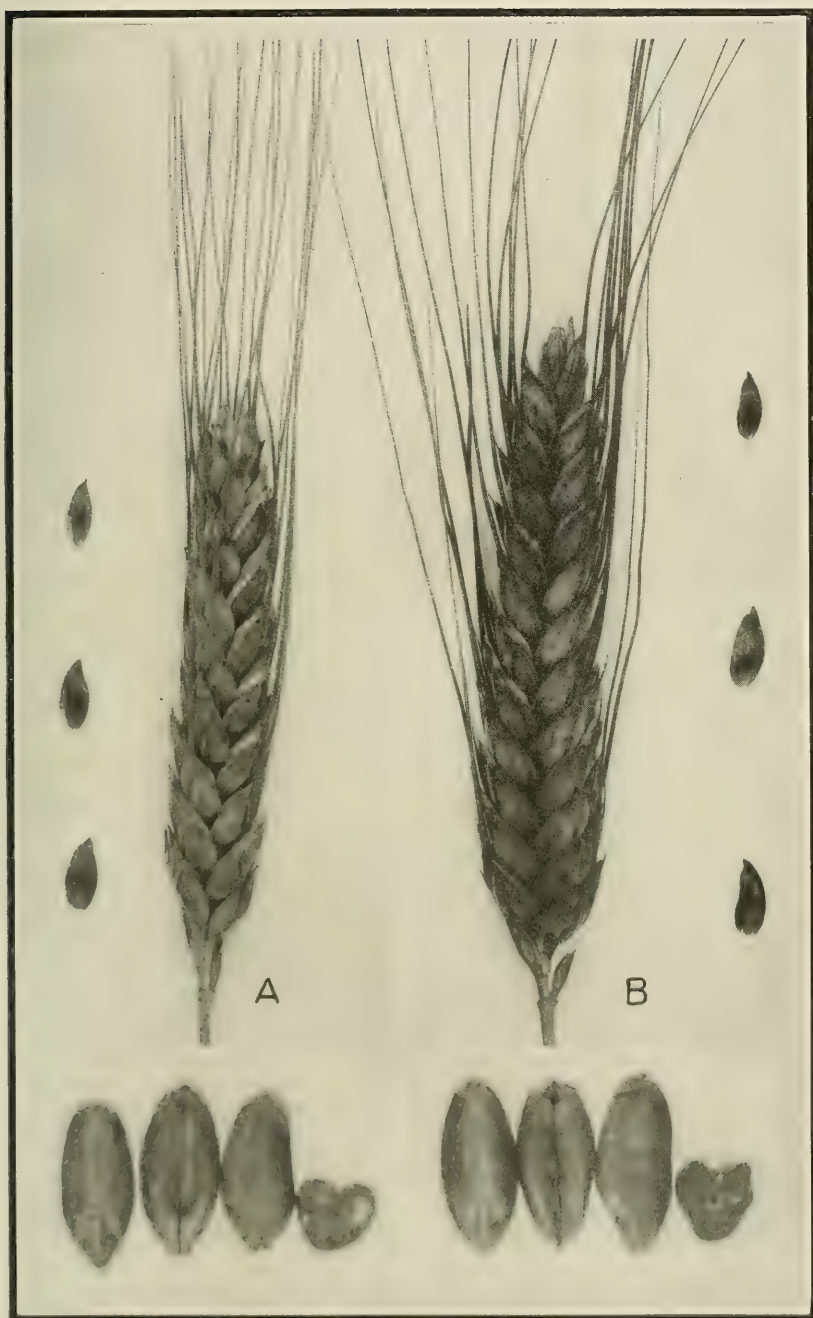
Synonym.—Black-Bearded durum. This name is used for Peliss by some growers in North Dakota not acquainted with its correct name.

ACME.

Description.—Plant spring habit, midseason, midtall; stem white, weak to midstrong; spike awned, fusiform, middense, inclined to nodding; glumes glabrous, yellowish, midlong, midwide; shoulders midwide, usually oblique; beaks broad, incurved, 1 mm. long; awns yellowish, 5 to 15 cm. long; kernels white (amber) midlong to long, hard, elliptical to ovate; germ mid-sized; crease midwide, shallow; cheeks angular; brush mid-sized, short.

Acme differs principally from Kubanka in being shorter, in having weaker straw, and a longer, laxer, and narrower spike. It is very resistant to stem rust and is a high-yielding variety. A spike, glumes, and kernels of Acme are shown in Plate LVI, A.

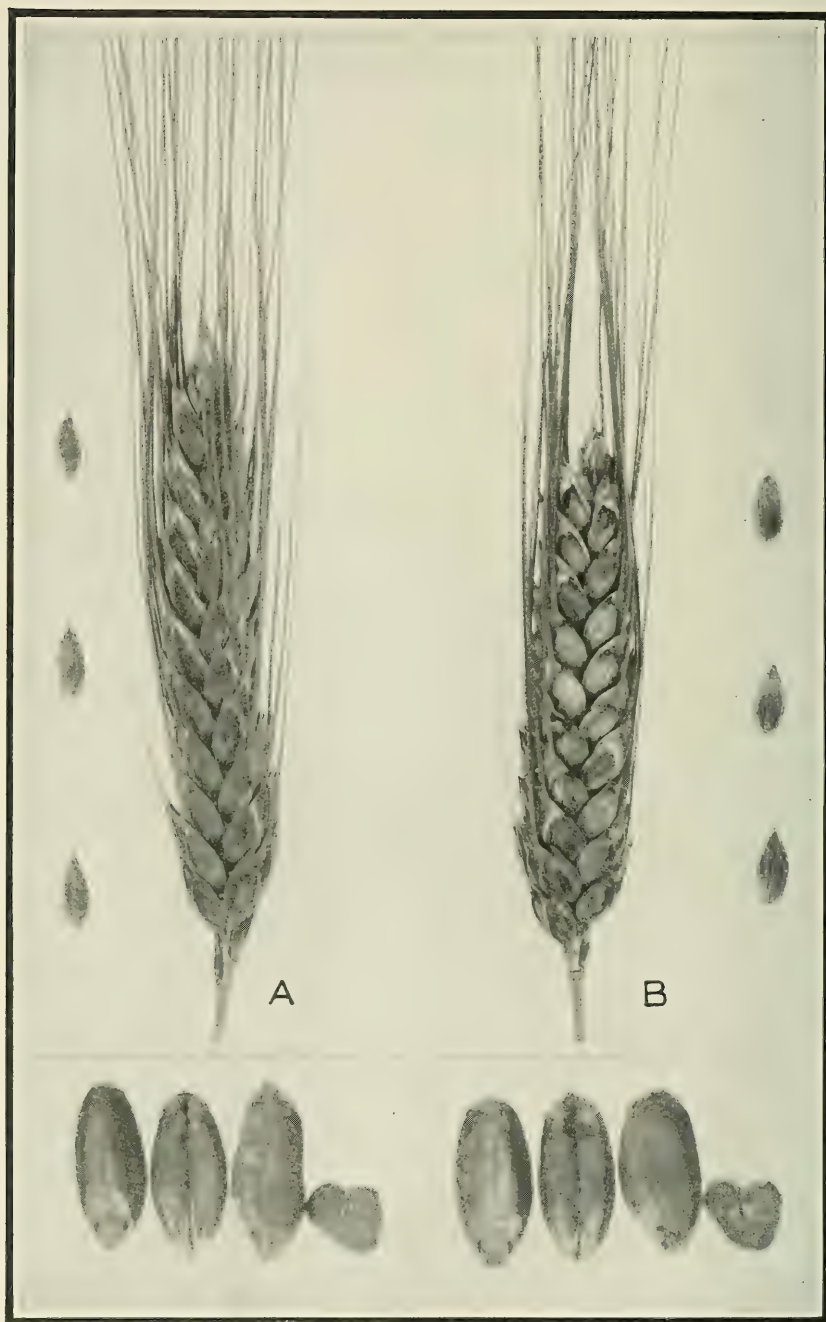
History.—The Acme variety originated as a pure-line selection from Kubanka (C. I. No. 1516) made by Manley Champlin, a representative of the United States Department of Agriculture, in cooperative experiments with the South Dakota Agricultural Experiment Station at the Highmore Substation, Highmore, S. Dak., in 1909. The selection was first known as No. 7. By 1914 it had been increased from the breeding nursery to the plats because of its high yields, and in 1916 it was grown commercially. In the rust epidemic of that year it was discovered to be resistant to stem rust. As it differs from the true Kubanka, it was given a distinctive name. The strain of Kubanka from which the Acme was selected was obtained by the United States Department of Agriculture at the Paris Exposition, in 1900. The seed came from the Samara Government, Russia. Although introduced and grown under the name of Kubanka, this lot is not identical with the true Kubanka and is much like Acme, but was not pure or as resistant to rust.



ACME (A).

KAHLA (B).

pike, side view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.



ARNAUTKA (A).

KUBANKA (B).

Spike, side view, natural size; glumes from lower, central, and upper portions of spike, natural size; kernels in three positions and in transverse section, magnified 3 diameters.

Distribution.—Acme is grown in experiments at experiment stations in the northern Great Plains area and commercially in North Dakota, South Dakota, and Wyoming.

MONAD.

Description.—The Monad variety is very similar to Acme, differing principally in having somewhat stronger stems and shorter awns. It is as resistant to stem rust as Acme and usually yields better than Acme in North Dakota, and the grain is of better milling quality.

History.—Monad wheat was introduced in 1903 from the Saratov Government, Russia, 100 versts east of Volga (unpublished S. P. I. No. 10207), by Prof. H. L. Bolley, of the North Dakota Agricultural Experiment Station, while making a study of the flax industry of Europe for the United States Department of Agriculture. Seed of the variety was distributed by Professor Bolley to several farmers and to the Dickinson and Langdon substations as D-1 (Durum No. 1) in 1911. Its identity on the farms nearly became lost. In 1917 it was named Monad by Ball and Clark (42, p. 44) after it was found in experiments at the Dickinson substation, Dickinson, N. Dak., to be a high-yielding variety and one resistant to stem rust. The name is derived from mono, root of the Greek word one, plus *d*, which stands for durum. It was increased at the Dickinson substation from 1918 to 1920 for commercial distribution. In 1920 R. S. Goodhue (96), county agent, of Stutsman County, N. Dak., reported finding the variety commercially grown in his county from one-half bushel of seed originally furnished O. J. Seiler, of Stutsman County, by Professor Bolley in 1911. August Clemens, of Lenton Township, obtained seed from Mr. Seiler and increased and grew it until 1919, when he brought it to the attention of County Agent Goodhue, who distributed 3,700 bushels among farmers in Stutsman County in the spring of 1920.

Distribution.—The Monad variety is grown in experiments at experiment stations in the northern Great Plains and commercially in North Dakota.

Synonym.—D-1. As shown above, this is the designation under which Professor Bolley first distributed seed of the Monad variety. It is still used as a name for the variety in Stutsman County, N. Dak., where it is grown to a considerable extent.

ARNAUTKA.

Description.—Plant spring habit, midseason, tall; stem white, midstrong; spike awned, fusiform, riddense, nodding; glumes glabrous, yellowish, midlong, midwide; shoulders narrow, usually oblique; beaks wide, 1 to 5 mm. long; awns yellowish, 6 to 18 cm. long; kernels white, long, hard, elliptical; germ mid-sized; crease midwide, shallow; cheeks angular; brush mid-sized, short.

Arnautka differs from Kubanka in having a longer, narrower, and laxer spike, which usually is more nodding when ripe. A spike, glumes, and kernels of Arnautka wheat are shown in Plate LVII, A.

History.—The first importation of Arnautka wheat made by the United States Department of Agriculture was in 1864 (157). It was grown in 1865 with other varieties of wheat on what are now the grounds of the Department of Agriculture, near Fourteenth Street, Washington, D. C. (42, p. 3). It was distributed to several sections of the United States, but as far as known never became commercially established. The basis for the present commercial stock is thought to have been brought by early immigrants from Russia to North Dakota (58, p. 40), where it was called Wild Goose. Distribution from

this source by the Department of Agriculture dates from 1900, when seed (C. I. No. 1494) was obtained from T. N. Oium, of Lisbon, N. Dak. This seed was distributed with Kubanka and other varieties. The variety, however, had previously become established in southeastern North Dakota, where it early proved to be well adapted. A pure-line selection (C. I. No. 4064) from this mass variety, developed at the Akron Field Station, Akron, Colo., has recently been grown at most agricultural experiment stations in the northern Great Plains and distributed somewhat.

Distribution.—Durum wheat was reported in 1919 from 29 States, but the proportion of this which Arnautka represents can not be determined. The variety is extensively grown, however, in Colorado, Minnesota, Montana, North Dakota, South Dakota, Texas, and Wyoming.

Synonyms.—Goose, Johnson, Nicaragua, Pierson, Wild Goose.

Goose and Wild Goose are names commonly used for Arnautka, or durum wheat in general, particularly by the grain trade, during the early years of durum-wheat cultivation in the United States. There is a tradition that the seed was originally obtained from the crop of a wild goose.

Johnson is a name under which Arnautka was reported from Michigan. The name is also in use in Iowa, Minnesota, South Dakota, and Wisconsin, but not usually for the Arnautka variety.

Nicaragua is a name used for Arnautka durum wheat in the southern Great Plains, particularly Texas. The source of this wheat is not known. In discussing its origin Carleton (58, p. 40) mentioned "one would infer from the name that it came from Nicaragua." It became grown throughout northern Texas in the early nineties and it is still grown there to a considerable extent. It is identical with the Arnautka variety.

Pierson is the name under which a selected lot of durum wheat identical with Arnautka has been distributed by George H. Pierson, of Claremont, S. Dak., with the claim that it was a rustproof durum wheat. Concerning this wheat, Mr. Pierson has written as follows:²¹

I obtained the seed 17 years ago (1897) from an immigrant who was driving through the State of South Dakota and using it for horse feed. The man was from Kansas and said that they used this wheat for horse and hog feed there. I raised it for some years as a horse and hog feed and then commenced to breed it. It is rustproof with a large head and hardy stiff straw. It outyields all other varieties.

MINDUM.

Description.—Mindum is similar to Arnautka, except for being slightly earlier, in having slightly weaker straw, narrower glumes, longer awns, a shorter or nearly absent brush, and in being more resistant to stem rust.

History.—Mindum was first grown in 1896 in a centgener nursery at University Farm, St. Paul, Minn., as a selection from wheat which was called "Hedgerow," by the Minnesota station.

The statement was made in the Minnesota accession book that it was a head selection from a field of common wheat. It proved to be a rust-resistant strain at University Farm, and was tested at the substations. It was a high-yielding wheat in experiments conducted at the Northwest substation at Crookston, Minn., during the years 1913 to 1916. The variety was named Mindum (a contraction of Minnesota durum) in 1918 (106, p. 33), for the purpose of distinguishing it from the commercial Arnautka.

Distribution.—Mindum was first distributed for commercial sowing in 1917 from University Farm, St. Paul, and from the Northwest substation, Crookston, Minn. Grown especially in Kittson and Red Lake Counties, Minn.

²¹ Correspondence of the Office of Cereal Investigations, dated May 30, 1914.

KUBANKA.

Description.—Plant spring habit, midseason, tall; stem white, midstrong; spike awned, broadly oblong, dense, inclined to nodding; glumes glabrous, yellowish, midlong, wide; shoulders midwide, usually rounded; beaks wide, 1 mm. long; awns yellowish, 6 to 15 cm. long; kernels white (amber), large, hard, elliptical; germ mid-sized; crease midwide, shallow; cheeks angular; brush mid-sized, short.

Kubanka is a high-yielding variety and is more resistant to stem rust than Arnautka. It differs from Arnautka in having shorter, denser, and more erect spikes, and shorter beaks and kernels. It also is a better milling variety than Arnautka. A spike, glumes, and kernels of Kubanka wheat are shown in Plate LVII, B, and a single spike in Plate IV, Figure 6.

History.—The Kubanka variety is of Russian origin. More than a dozen importations into the United States have been made. The principal introduction of the variety was made in 1900 by M. A. Carleton, of the United States Department of Agriculture, from Uralsk Territory, Russia (197, S. P. I. No. 5639). The original seed of this introduction was grown under contract in New Mexico and South Dakota in 1901, and the following year 200 bushels of seed were distributed to many growers. The distribution was continued by the Department up to 1909. Aside from the distribution made by the United States Department of Agriculture, both the North Dakota and South Dakota experiment stations distributed large quantities to growers. The Kubanka first proved specially well adapted to the drier western portions of the Great Plains area. In recent years it has proved well adapted to the more humid sections also and is now considered the best adapted of the durum varieties to all of the varying conditions in the northern spring-wheat section of the United States.

Distribution.—Grown in Colorado, Minnesota, Montana, North Dakota, South Dakota, Wisconsin, and Wyoming. Durum wheat was reported from a dozen other States in 1919, but it can not be determined just what proportion of the distribution shown is of the Kubanka variety.

Synonyms.—Beloturka, Gharnovka, Pererodka, Taganrog, and Yellow Gharnovka.

Beloturka (meaning white Turk) is of Russian origin and, like Kubanka, has also been introduced into the United States many times. The wheat received under this name has proved to be similar to Kubanka. In both Russia and Algeria, where Beloturka wheat is widely grown, the name is used as synonymous with Kubanka.

The Gharnovka variety was obtained in two lots (197, S. P. I. Nos. 5643 and 5646) from Taganrog, Territory of the Don Cossacks, Russia, by M. A. Carleton, for the United States Department of Agriculture in 1900. These both proved to be very similar to Kubanka, and they were grown in experiments in the northern Great Plains for a number of years, but have now been discontinued at most points because they did not prove to be superior to Kubanka in yield.

Pererodka was first obtained by M. A. Carleton, for the United States Department of Agriculture in 1899 from the Orsk district, Orenburg Government, Russia (197, S. P. I. No. 2954). Concerning the name of this wheat Carleton (59, p. 18) has written as follows:

This wheat is very closely allied to Kubanka. The word Pererodka means something regenerated or degenerated. In the case of its application to this sort of wheat, it is apparently understood to have the latter meaning. As already stated, when Kubanka wheat, by transference to darker soil, becomes softer and darker grained, it is called Pererodka.

The Pererodka variety was grown in experiments for a number of years in the northern Great Plains and appeared to be identical with Kubanka in all respects.

Taganrog (197, S. P. I. No. 5355) is the name under which a wheat similar to Kubanka was obtained from Marseilles, France, in 1900, by W. T. Swingle, of the United States Department of Agriculture. This is not a varietal name in France, but rather the name of a port of Russia, and the sample introduced was probably a bulk lot of seed shipped from Taganrog.

Yellow Gharnovka (197, S. P. I. No. 5642) has the same history as Ghar-novka discussed above.

KUBANKA NO. 8.

Description.—Kubanka No. 8 is a selection from Kubanka, identical in appearance but a better yielder in western North Dakota. It is much more susceptible to stem rust than the unselected Kubanka and principally for that reason has not yielded well over a wider area.

History.—Kubanka No. 8 (C. I. No. 4063) is a pure-line selection from Kubanka (C. I. No. 1440) made in 1906 by Prof. L. R. Waldron, now of the North Dakota Agricultural Experiment Station, at the Dickinson Substation, Dickinson, N. Dak., where it proved to be a high-yielding strain (64, p. 17).

Distribution.—It was distributed to growers in the vicinity of Dickinson as early as 1911, and has been grown commercially since in western North Dakota and at most experiment stations in the northern Great Plains area.

BUFORD.

Description.—Buford is similar to Kubanka, except that it has a slightly narrower and laxer spike. It proved to be a high-yielding variety at the Williston substation, Williston, N. Dak., but it has a gluten of poor quality, as shown by a small loaf volume.

History.—Buford is the result of a pure-line selection made by F. R. Babcock, a representative of the United States Department of Agriculture, at the Williston substation, Williston, N. Dak., in 1909. This selection was made from a plat of Taganrog. It was first grown in plat experiments in 1913, when it out-yielded all other varieties grown. It continued to yield well and in 1917 was given the name Buford, from the Buford-Trenton Reclamation Project, on which the Williston substation is located, and was distributed (42, p. 46).

Distribution.—Grown in Williams and Divide Counties, N. Dak., and in Montana.

MAROUANI.

Description.—Plant spring habit, midseason, very tall; stem white, weak; spike awned, broadly oblong, dense, nodding; glumes glabrous, yellowish, mid-long, wide; shoulders narrow, usually elevated; beaks wide, 1 to 15 mm. long; awns yellowish, 8 to 20 mm. long; kernels white (amber), very long, hard, elliptical, humped; germ large; crease midwide, shallow to middeep; cheeks angular; brush small, short.

History.—Marouani wheat (197, S. P. I. No. 7578) was introduced from the Province of Oran, Algeria, in 1901, through D. G. Fairchild and C. S. Scofield, for the United States Department of Agriculture. Concerning the introduction, they have written as follows:

This wheat is cultivated extensively on the elevated rolling lands in the western part of the Province and is one of the best of the types of durum wheats cultivated by the Arabs. The quantity obtained is from the estate of M. J.

Labouresse, at Tessala, near Sidi bel Abbes. It has been carefully selected by Mr. Labouresse from year to year until a fairly pure and very vigorous stock has been obtained. The variety is very hardy, resistant to rust, and succeeds fairly well under rather droughty conditions. The grain is especially adapted for the manufacture of semolina. In the Province of Oran the wheat is sown in November and ripens in June, but it might succeed as a spring wheat in the spring-wheat region of the northern United States.

In experiments in the United States Marouani wheat proved best adapted to the central and southern Great Plains.

Distribution.—Marouani has been distributed from the Hays Branch Station, Hays, Kans., and the Amarillo Field Station, Amarillo, Tex. The extent of its present distribution is not known, as it was not reported in the varietal survey.

VELVET DON.

Description.—Plant spring habit, midseason, midtall; stem white, midstrong; spike awned, fusiform, middense, inclined; glumes pubescent, white, midlong, midwide; shoulders narrow, oblique to elevated; beaks wide, 1 to 1.5 mm. long; awns black, 6 to 15 cm. long; kernels usually white (amber) midlong to long, hard, ovate to elliptical, humped; germ mid-sized; crease midwide, shallow to middeep; cheeks angular; brush mid-sized, short.

Velvet Don as originally introduced was a mixture as to kernel color, a considerable percentage of red kernels being present. It has sometimes been described as a red-kerneled variety. That which is grown now, however, is usually white kerneled.

History.—Velvet Don (197, S. P. I. No. 5644) was introduced from Ambrocievka, 20 miles northeast of Taganrog, in the Don Territory, Russia, in 1900, by M. A. Carleton, for the United States Department of Agriculture. Experiments with Velvet Don in the United States have proved it to be only a mediocre yielder, and it now is largely discontinued in experiments.

Distribution.—Seed of the variety was distributed by the Department at various times in the early nineties and the variety is commercially grown to a limited extent in Montana and Nebraska.

GOLDEN BALL.

Description.—Plant spring habit, midseason, short to midtall; stem white, midstrong; spike awned, oblong-fusiform, dense, inclined; glumes pubescent, white, midlong, midwide; shoulders narrow, oblique to elevated; beaks 1 to 5 mm. long; awns black, 5 to 18 cm. long; kernels white, long, hard, ovate, humped; germ large; crease midwide, shallow to middeep; cheeks angular; brush small, short.

History.—Golden Ball (197, S. P. I. No. 46766) was introduced by the United States Department of Agriculture in 1918, from Johannesburg, South Africa. The seed was purchased through J. Burt Day from the Agricultural Supply Association. Three previous introductions of wheat under the name of Golden Ball had been made by the department from South Africa. These wheats all resemble this introduction, except that they had red instead of white kernels. The Golden Ball is reported to be extensively grown in South Africa and is recognized as a valuable drought-resistant and rust-resistant variety.

Distribution.—Seed of the introduction discussed above has been distributed to field stations of the Office of Cereal Investigations in the northern Great Plains and Pacific Northwest. It is not grown commercially.

KAHLA.

Description.—Plant spring habit, midseason, tall; stem white, midstrong; spike awned, oblong-fusiform, middense, nodding; glumes finely pubescent, black, midlong, midwide; shoulders narrow, usually oblique; beaks wide, 1 to 2 mm. long; awns black, 6 to 16 cm. long; kernels white (amber) midlong to long, hard, elliptical, humped; germ mid-sized; crease midwide, middeep; cheeks angular; brush mid-sized, short.

A spike, glumes, and kernels of Kahla are shown in Plate LVI, B.

History.—The Kahla variety (197, S. P. I. No. 7794) was introduced in 1901 by Messrs. D. G. Fairchild and C. S. Scofield, from Setif, Constantine Province, Algeria, for the United States Department of Agriculture. Concerning the variety they recorded the following information:

This is one of the wheats commonly grown by Arabs throughout Algeria. As the name Kahla signifies, this is a black-chaffed sort. It is generally considered to be one of the best of the Algerian wheats for adaptability to a wide variety of adverse conditions. When such are favorable it produces grain of excellent quality for macaroni manufacture. Under certain favorable climatic conditions the chaff loses color somewhat, but under native culture on the gravelly hills of Algeria or in the semiarid plains the purple-black of the chaff is a striking feature. This seed is furnished the department by Mr. G. Ryf, manager of the Geneva Society of Setif. Commonly planted in November or December and harvested in June or July.

Experiments with Kahla wheat showed it to be a fairly good yielding variety, but not superior to Kubanka.

Distribution.—After being grown in experiments for a series of years in many sections of the northern Great Plains, its culture largely has been discontinued. Small lots are known to have been distributed, however, and apparently the wheat has become established on farms, especially in Montana, North Dakota, and South Dakota, and known by various names.

Synonyms.—Black Don, Black Durum, Black Emmett, Black Swamp, Purple Durum, Red Swamp, and Sloat.

Black Don (197, S. P. I. No. 5645) is a wheat similar to Kahla except that (like Velvet Don) it usually is mixed in kernel color, a considerable percentage of red kernels being present. The variety is of Russian origin. It was introduced in 1900, from Ambrocievka, 20 miles northeast of Taganrog, in the Don Territory, Russia, by M. A. Carleton for the United States Department of Agriculture. In experiments in the United States this variety did not prove superior to Kubanka and it now largely has been discontinued. It is possible, however, that this variety may be commercially grown.

Black Durum is the name under which wheat similar to Kahla is commercially grown in Montana. Its distribution apparently started from Fergus County. Black Emmett is the name commonly used for a wheat, apparently similar to Kahla, in North Dakota, the distribution of which apparently started in Hettinger County. Purple Durum is a name used for Kahla in Wyoming. Black Swamp and Red Swamp are names under which a wheat practically identical with Kahla was obtained from Morrow County, Oreg., where it is grown to a very small extent. Sloat descended from a head selection made by Sloat Bros., of Gettysburg, S. Dak. They state that a single head of black-chaff wheat was found in a commercial field of Kubanka, and from this originated the wheat they have been growing and distributing as Sloat. This strain apparently is identical with Kahla. Its distribution dates from 1917.

EMMER.

Emmer is often incorrectly called "Speltz" in the United States. The word emmer is German, but it has come into use in America, as there is no English name for this wheat ally. Emmer may be of either winter or spring habit and usually is awned. The culms often are pithy within and the leaves usually are pubescent. The rachis is brittle. The spikes are very dense and laterally compressed, being narrow when viewed from the face of the spikelet and wide from the edge view. The pedicel (joint of rachis) is short, narrow, and pointed, and remains attached to the base of the spikelet which it bears. The spikelets are flattened on the inner side and usually contain two flowers. The kernels, which remain inclosed in the

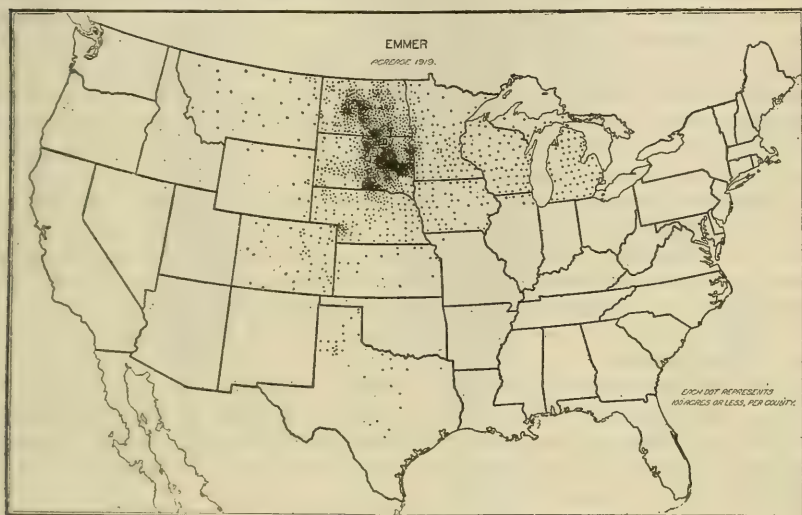


FIG. 76.—Outline map of the United States, showing the distribution of emmer in 1919, according to the United States Census. Estimated area, 166,829 acres. Each dot represents 100 acres or less, per county.

glumes after thrashing, are red, long, and slender with both ends acute.

Emmer is distinguished from spelt by the shorter, denser spikes, which are laterally compressed. The pedicel of emmer is shorter and narrower and is usually attached to the base of the spikelet which it bears, while in spelt the pedicel remains attached to the face of the next lower spikelet. The inner side of the spikelet is flat instead of arched, and the kernel usually is of a darker red color than that of spelt.

Practically all of the emmer grown in the United States is used as feed for live stock. Some winter emmer, however, is used in the manufacture of breakfast food. The distribution of emmer in 1919 is shown in Figure 76.

KEY TO THE VARIETIES OF EMMER.

	Page.
SPIKE AWNED.	
GLUMES GLABROUS.	
GLUMES WHITE (<i>Triticum dicoccum farrum</i> Bayle).	
SPRING HABIT.	
Straw white.	
Plant early, short ----- KHAPLI -----	194
Straw purple.	
Plant late, midtall ----- VERNAL -----	194
GLUMES PUBESCENT.	
GLUMES BLACK (<i>T. d. atratum</i> Al.).	
WINTER HABIT ----- BLACK WINTER -----	195

DESCRIPTIONS, HISTORY, DISTRIBUTION, AND SYNONYMY OF EMMER VARIETIES.

KHAPLI.

Description.—Plant spring habit, early, short; stem white, midstrong; spike awned, broadly oblong, middense, inclined; glumes glabrous, white, midlong, narrow; shoulders midwide, oblique to elevated; beaks wide, obtuse, 0.5 mm. long; awns white, 2 to 12 cm. long; kernels red, long, hard, elliptical, acute, humped, curved, usually remaining in the glumes when thrashed; germ small; crease narrow to midwide, shallow; cheeks usually rounded; brush small, long.

Khapli differs from the common White Spring emmer chiefly in being earlier and in having shorter stems and wider spikes.

History.—A sample of this emmer was first obtained in 1908 by the Department of Agriculture from Hoshungabad, Central Provinces, India. Seed was grown at University Farm, St. Paul, Minn., and the variety has proved of interest and value for breeding, because of its immunity from stem rust. The variety has yielded well in experiments in South Dakota.

Distribution.—Grown to a slight extent in South Dakota and at several experiment stations.

Synonym.—Kathiawar is an emmer similar to Khapli. It was obtained in 1914 and again in 1915 (197, S. P. I. Nos. 39227 and 40919) by the United States Department of Agriculture, from the district of Kathiawar, north of Bombay. It is said to grow wild in Kathiawar, a very dry district on the west coast of India, but there is no proof of this.

VERNAL (WHITE SPRING.)

Description.—Plant spring habit, late, midtall; stem purple, midstrong; spike awned, fusiform, middense, nodding; glumes glabrous, white, midlong, midwide; shoulders midwide, oblique; beaks wide, obtuse, 0.5 mm. long; awns white, 2 to 12 cm. long; kernels red, long, hard, ovate to elliptical, acute, humped, usually remaining in the glumes when thrashed; germ small; crease narrow to midwide, shallow; cheeks usually rounded; brush small, long.

A spike, glumes, a spikelet, and kernel of Vernal (White Spring) emmer are shown in Plate LVIII, A.

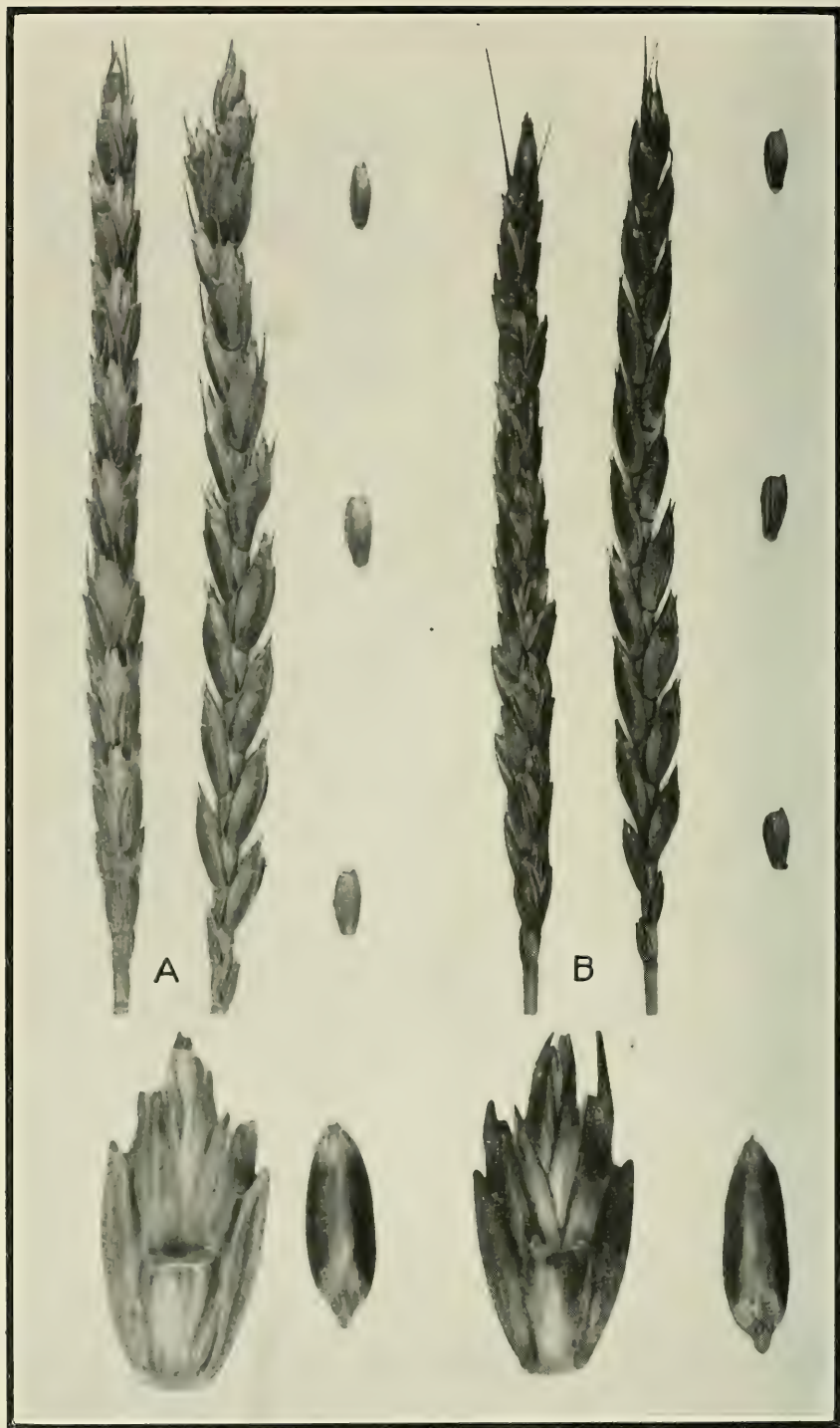
History.—The origin of emmer dates from prehistoric times. In historic times it seems to have been cultivated first in Switzerland. It is now grown extensively in Germany and Russia, where the White Spring emmer as above described is the most common variety. It is not known when this variety was first brought to the United States, but it was grown by farmers in the northern Great Plains States probably as early as 1875. In recent years its cultivation has greatly increased. It has long been called White Spring, but is here named Vernal.



VERNAL EMMER (A).

BLACK WINTER EMMER (B).

-pike, side view, natural size; glumes from lower, central, and upper portions of spike, natural size; spikelet and kernel, magnified 3 diameters.



WHITE SPRING SPELT (A)

RED WINTER SPELT (B).

Spikes, face and side views, natural size; glumes from lower, central, and upper portions of spike, natural size; spikelet and kernel, magnified 3 diameters.



WHITE POLISH (A).

EINKORN (B).

Spike, side view, natural size; plume— from lower, central, and upper portion of spike, natural size; wheat kernels in three positions and in transverse section, magnified 3 diameters; einkorn spikelet and kernel, magnified 3 diameters.

Distribution.—Grown to a considerable extent in Minnesota, North Dakota, South Dakota, and to a lesser extent in Colorado, Kansas, Montana, Nebraska, Oklahoma, Texas, and Wyoming.

Synonyms.—"Speltz" and Yaroslav emmer.

"Speltz" is the name under which White Spring emmer usually is advertised and sold by seedsmen in the Great Plains States. It usually is known by that name on the farms also. This term is incorrectly used, and the name does not exist as a legitimate word in any language. What is meant is the German word *Spelz*, which is spelled differently and which is translated spelt in English. The confusion between emmer and spelt is thought to have arisen in Germany, where considerable quantities of both cereals are grown.

Yaroslav emmer (197, S. P. I. No. 2789) was obtained from the Government of Yaroslav, Russia, in 1899, by M. A. Carleton, for the United States Department of Agriculture. Experiments with this introduction in the United States have shown it to be practically identical with White Spring emmer. As it has not outyielded the White Spring emmer in experiments, it has not become commercially grown.

BLACK WINTER.

Description.—Plant winter habit, late, tall; stem white, strong, stout; spike awned, broadly fusiform, middense to dense, inclined; glumes pubescent, black, midlong, midwide; shoulders midwide, usually elevated; beaks wide, 1 mm. long; awns black, 4 to 15 cm. long; kernels red, long, hard, elliptical, acute, curved, inclosed in hull when thrashed; germ small; crease midwide, shallow; cheeks angular; brush small, long.

Black Winter emmer is quite distinct in having pubescent black glumes. Unlike the varieties of spring emmer, this variety is very susceptible to rust. A spike, glumes, a spikelet, and kernels of Black Winter emmer are shown in Plate LVIII, B.

History.—Black Winter emmer (197, S. P. I. No. 11650) was obtained in 1904 from Vilmorin-Andrieux & Co., Paris, France, by the United States Department of Agriculture. The original importation of 79 pounds of seed was sown in the fall of 1904. From the resulting crop seed was increased and distributed to experiment stations and a number of farmers throughout the United States. The results of experiments since that time have been unfavorable. The variety has not proved sufficiently hardy for growing successfully north of Kansas and Wyoming in the Great Plains area, and has not been able to compete with other cereals in the southern Great Plains.

Distribution.—Grown in experiments in the central and northern Great Plains and commercially to a small extent in Colorado, Kansas, Oklahoma, Texas, Washington, and Wyoming.

Synonym.—Buffum's Improved Winter emmer. This is identical with the emmer described, but is a pure strain and consequently more uniform. Buffum's Improved Winter emmer was distributed by B. C. Buffum, of Worland, Wyo. When director of the Wyoming Agricultural Experiment Station at Laramie he received a small quantity of seed of Black Winter emmer from the Office of Cereal Investigations. After his resignation he selected and improved the crop. From a dozen selected plants of the 1908 crop 34 bushels were produced in 1909, 710 bushels in 1910, and a crop of 20,000 bushels was estimated in 1911. This seed was widely distributed.

SPELT.

Spelt may be of either winter or spring habit and awnless or awned. It has a long, narrow, lax spike and a brittle rachis. The

pedicel (joint of the rachis) is long and wide, and after thrashing remains attached to the face of the spikelet below the one which it bears. The spikelets are two-kerneled, arched on the inner side, and closely appressed to the rachis. The kernels, which remain inclosed in the glumes after thrashing, are pale red, long, and laterally compressed, and have an acute tip and a narrow, shallow crease.

Spelt is grown commercially only to a slight extent in America. The varieties often called "Speltz" in this country are not spelt but emmer. A few varieties chiefly grown experimentally are separated in the following key:

KEY TO THE VARIETIES OF SPELT.

SPIKE AWNLESS.

GLUMES GLABROUS.

GLUMES WHITE (<i>Triticum spelta album</i> Al.).		Page.
SPRING HABIT	WHITE SPRING	196
WINTER HABIT	ALSTROUM	196
GLUMES BROWN (<i>T. s. rufum</i> Al.).		
WINTER HABIT	RED WINTER	197

SPIKE AWNED.

GLUMES GLABROUS; WHITE (*T. s. arduinii* Al.).

WINTER HABIT	BEARDED	197
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DESCRIPTIONS, HISTORY, AND DISTRIBUTION OF SPELT VARIETIES.

WHITE SPRING.

Description.—Plant spring habit, late, midtall; stem white, strong; spike awnless, linear-fusiform, lax, erect; glumes glabrous, white, midlong, wide; shoulders wide, square; beaks wide, obtuse, 0.5 mm. long; awns few, 1 to 8 mm. long; kernels red, long, semihard, elliptical, humped, curved, inclosed in glumes; germ small; crease wide, shallow, pitted; cheeks angular; brush mid-sized, long.

A spike, glumes, a spikelet, and kernels of White Spring spelt are shown in Plate LIX, A.

History.—Obtained by the Department of Agriculture from J. M. Thorburn & Co., seedsmen, of New York City, in 1904.

Distribution.—Grown in experiments in North Dakota, but not known to be grown commercially.

ALSTROUM.

Description.—Plant winter habit, late, midtall; stem faintly purple, strong; spike awnless, linear-fusiform, lax, inclined to nodding; glumes glabrous, white, midlong, narrow; shoulders midwide, square; beaks obtuse, 0.5 mm. long; apical awns usually wanting; kernels red, long, semihard, elliptical, humped, curved, inclosed in glumes; germ small; crease wide, shallow; cheeks angular; brush mid-sized, long.

Alstrom differs from White Spring spelt chiefly in having a winter habit.

History.—Alstrom spelt was obtained by the United States Department of Agriculture in 1901 from the Washington Agricultural Experiment Station, Pullman, Wash. Its further history is undetermined.

Distribution.—Grown in experiments at Arlington Experimental Farm, Va., and by the Washington station, Pullman, Wash. It is known to be commercially grown to a slight extent.

RED WINTER.

Description.—Plant winter habit, late, midtall; stem faintly purple, strong; spike awnless, linear-fusiform, lax, erect; glumes glabrous, brown, midlong to long, wide; shoulders wide, square; beaks obtuse, 0.5 mm. long; apical awns few, 3 to 20 mm. long; kernels red, long, soft, humped, curved, usually inclosed in glumes; germ small; crease wide, shallow; cheeks angular; brush midsized, long.

This variety differs from Alstroum spelt in having brown glumes. A spike, glumes, a spikelet, and kernels of Red Winter spelt are shown in Plate LIX, *B*.

History.—Red Winter spelt was first obtained by the United States Department of Agriculture in 1901 from the Washington Agricultural Experiment Station. Its further history is undetermined. Many samples of this and other spelt varieties doubtless have been introduced into the United States from time to time. A sample of spelt practically identical with the above was introduced from Switzerland about 1913 by Paul Scheddiger, of Spearfish, S. Dak., and was distributed by him in 1915. Most of this winterkilled during the next two winters, which were unusually severe.

Distribution.—Formerly grown to a small extent in South Dakota and Wyoming. Now grown only by experiment stations.

BEARDED.

Description.—Plant winter habit, late, midtall; stem faintly purple, strong; spike awned, linear fusiform, lax, erect; glumes glabrous, yellowish, midlong, midwide; shoulders wide, apiculate; beaks wide, acute, 0.5 mm. long; awns yellowish, 2 to 10 cm. long; kernels red, large, soft, curved, humped, usually inclosed in glumes; germ small; crease wide, shallow, pitted; cheeks angular; brush midsized, long.

History.—Same as Alstroum.

Distribution.—Grown in experiments at Arlington Experimental Farm, Va. Not known to be commercially grown.

POLISH WHEAT.

Polish wheat has a spring habit, tall stems, and a pithy peduncle. The spike is awned, large, and lax. The glumes are papery, an inch or more long, and narrow. The length of the glume equals or exceeds the length of the lemmas. The kernel is long and narrow, sometimes nearly a half inch long, hard, and has a shape somewhat similar to that of a kernel of rye.

Polish wheat usually yields less than other adapted varieties. It also is of inferior value for bread or macaroni manufacture. Under other names it is frequently sold at a high price for seed by unscrupulous seedsmen. Only one variety of Polish wheat is grown in the United States. The characters of this variety are shown in the following key:

KEY TO POLISH WHEAT.

SPIKE AWNED.

GLUMES GLABROUS; WHITE.

KERNELS WHITE (*Triticum polonicum levissimum* Haller.).

KERNELS LONG TO VERY LONG; HARD.

SPRING HABIT-----	WHITE POLISH-----	Page.
		198

DESCRIPTION, HISTORY, DISTRIBUTION, AND SYNONYMY OF POLISH WHEAT.

WHITE POLISH.

Description.—Plant spring habit, early, tall; stem white, weak; spike awned, linear-oblong, lax, nodding; glumes glabrous, white, paperish, very long, narrow; shoulders usually wanting; beaks narrow, acute, 0.5 to 1 mm. long; awns black, usually deciduous, 4 to 10 cm. long; kernels white (amber) very long, hard, elliptical, acute; germ mid-sized; crease narrow, shallow to middeep; cheeks usually rounded; brush large, midlong.

A spike, glumes, and kernels of White Polish wheat are shown in Plate LX, A.

History.—This wheat is not definitely known to be of Polish origin, as the name implies. It has been grown in England and other European countries for many years, and was early introduced into the United States. It is known to have been grown in Maryland as early as 1845 (180, p. 413). From that time until the present frequent references can be found concerning the variety. It has often been used for exploitation by unscrupulous growers or seedsmen, the seed often being sold for as much as \$1 a pound. It has been tried in most sections of the United States, but has never become established anywhere for more than a year or two. It is usually a poor yielder, although it has produced large yields in some sections. It is difficult to market this wheat in the United States for purposes other than for feed.

Distribution.—Polish wheat was reported in 1919 only from New Mexico and Wyoming. It is known, however, to be grown sparingly in Idaho, Montana, Nebraska, North Dakota, and South Dakota, and is doubtless grown to a slight extent in many other States.

Synonyms.—Belgian rye, Corn wheat, German rye, Giant rye, Goose wheat, Jerusalem rye, Rice wheat, Siberian Cow, and Wild Goose.

Belgian rye, German rye, Giant rye, and Jerusalem rye are names used by exploiters of Polish wheat because the spikes and kernels have a general resemblance to those of rye.

Corn wheat is the name applied to Polish wheat by W. J. Shields & Co., of Moscow, Idaho, about 1900, the reason stated for so naming it being that it makes the same kind of meal as corn. The exploitation of Polish wheat under this name was continued a number of years, and the wheat is still grown in Idaho under that name.

Goose and Wild Goose are names sometimes applied to Polish wheat, as well as to durum and poulard wheats.

Rice wheat is a name used for Polish wheat by many men in the grain trade. Siberian Cow is the name applied to Polish wheat in Nebraska, according to a report by Walter Fowler, grain supervisor of the United States Department of Agriculture at Omaha, Nebr.

EINKORN.

Einkorn, or 1-grained wheat, has no English name, but is called einkorn in German and that name has become fairly well known in America. The spikes are awned, narrow, slender, and laterally com-

pressed. The spikelets usually contain only one fertile floret, for which reason it is called 1-grained wheat. The terminal spikelets are aborted. The palea splits into two parts at maturity. The kernels, which remain in the spikelets after thrashing, are pale red, slender, and very much compressed. The kernel crease is almost wanting.

Einkorn is not commercially grown in America, and the species itself has no economic importance. The form most commonly grown experimentally is distinguished by the following key:

KEY TO EINKORN.

SPIKE AWNED.

GLUMES GLABROUS.

GLUMES WHITE (*Triticum monococcum vulgare* Kcke.).

Page.

WINTER HABIT-----EINKORN----- 199

DESCRIPTION, HISTORY, AND DISTRIBUTION OF THE VARIETY.

EINKORN.

Description.—Plant winter habit, although usually it will mature seed from spring sowing, late, short; stem white, fine, strong; spike awned, fusiform, middense, erect; glumes glabrous, yellowish, long, narrow; shoulders narrow, apiculate; beaks narrow, acuminate, 1 to 2 mm. long; awns 3 to 10 cm. long; kernels red, midsized, soft, elliptical, acute, humped, compressed, usually inclosed in glumes; germ small; crease narrow, nearly wanting, shallow; cheeks rounded; brush small, short.

This variety of einkorn is described as having a winter habit because the plant remains prostrate during most of the growing season. It usually will produce seed late in the season when sown in the spring and frequently has been grown as spring einkorn. A spike, glumes, a spikelet, and kernels of einkorn are shown in Plate LX, B.

History.—Einkorn apparently originated in southern Europe in prehistoric times. Seed of this cereal has been introduced into the United States several times, one of the earliest introductions by the department having been received from Vilmorin-Andrieux & Co., Paris, France, in 1901, but it is known to have been grown in the United States previous to that time. The strain here described was obtained from Erfurt, Germany, in 1904.

Distribution.—Grown by many experiment stations throughout the United States, but not known to be grown commercially.

UNIDENTIFIED VARIETIES.

Among the wheat varieties grown in the United States are a few which have not yet been identified. Nearly 300 names were reported in the varietal survey, of which no material has been obtained and grown. Seed of many of these was requested, but not received. Obviously, some of the names reported were not properly applied to wheat. Others are probably local names used by only a few growers, but not published or generally established. The names of varieties which were reported but not grown or identified by the writers are

shown in the following list, together with the State or States from which they were reported:

LIST OF UNIDENTIFIED VARIETIES OF WHEAT, SHOWING THE STATES FROM WHICH THEY WERE REPORTED.

[The history of each variety marked with a star (*) is recorded at the end of the list.]

Name of variety.	State or States where grown.
Amber King.....	New York.
Amber Red.....	New York.
America.....	Kentucky.
American Beauty.....	Indiana.
American Wonder.....	Pennsylvania.
Andacy.....	Alabama.
Anderson.....	Missouri.
Badger.....	Indiana.
Baltic.....	Oklahoma, Tennessee.
Bald.....	Indiana, Kansas, West Virginia.
Bartlette.....	Alabama.
Beardsley.....	Ohio.
Berkhead.....	Texas.
Big Flint.....	North Carolina.
Big White.....	Alabama, Georgia, North Carolina, South Carolina.
Bland.....	Missouri.
Blocher.....	Pennsylvania.
*Boughton.....	Virginia.
Bowden.....	Alabama, North Carolina, South Carolina, Tennessee, Virginia, West Virginia.
Box.....	Tennessee.
Broadhead.....	Oregon.
Brubaker.....	Michigan, Pennsylvania.
Bull.....	Illinois.
Bullhead.....	Kentucky.
Burns.....	Kentucky.
Camel.....	Pennsylvania.
*Canada Club.....	Colorado, Missouri, New York, Idaho.
Canadian Wonder.....	Pennsylvania.
Cap Chief.....	Wisconsin.
Carson.....	Washington.
*Castillione.....	South Dakota.
Centennial.....	Indiana.
Chamberlain.....	Illinois.
Clark's No. 2.....	New York.
College No. 9.....	Michigan.
Common Red.....	Missouri.
Congress.....	Pennsylvania.
Copper Head.....	Arkansas, Kentucky, Missouri.
Corkill.....	Texas.
Cranford Hybrid.....	New York.
Crooked Finger.....	Oregon.
Dallas.....	Georgia.
Delaware Red.....	Delaware.

LIST OF UNIDENTIFIED VARIETIES OF WHEAT—Continued.

Name of variety.	State or States where grown.
Dibbles.....	Vermont.
Dietz Prolific.....	Ohio.
Double Yield.....	Kentucky.
Duff.....	Illinois.
Early Champion.....	Iowa.
Early June.....	Tennessee.
Early Ohio.....	Oregon.
Early Red.....	Kentucky, Tennessee.
Echo.....	Idaho.
Econimus.....	Texas.
English.....	Indiana.
English Prolific.....	Virginia.
European.....	Illinois, Michigan, Ohio.
Farmer's Favorite.....	Indiana.
Fay's Prolific.....	Indiana.
Fly-Proof.....	Pennsylvania.
French Bloom.....	South Carolina.
Fuller.....	South Carolina.
Fultzo-Clawson.....	Pennsylvania.
Genesee Golden Chaff.....	Pennsylvania.
Genesee Red.....	Indiana, Michigan.
Geneva.....	California.
Gleason.....	North Carolina.
Glenn.....	California.
Gold Dust.....	Indiana, Ohio, West Virginia.
Golden.....	North Carolina.
Golden Amber.....	Illinois.
Goldengrain.....	Tennessee.
Golden Harvest.....	Michigan, Pennsylvania.
Golden Plush.....	Illinois.
Golden Red.....	North Carolina.
Golden Rock.....	Indiana.
Golden Rod.....	Ohio, West Virginia.
Golden Rule.....	Iowa.
Golden Seal.....	Missouri.
Good Quality.....	Ohio.
Goosebill.....	North Carolina.
Gordon.....	South Carolina.
Governor.....	Illinois.
Grant.....	Nebraska.
Griffith.....	Kentucky.
Hack.....	Ohio.
Hancock.....	Illinois.
Harvesting.....	Pennsylvania.
Hicks.....	Indiana.
Homaker.....	Illinois.
Hundredfold.....	Tennessee.
Hybrid No. 2.....	Michigan.
Hybrid No. 4.....	New York.
Hybrid Prolific.....	Michigan.
Improved No. 7.....	Michigan.

LIST OF UNIDENTIFIED VARIETIES OF WHEAT—Continued.

Name of variety.	State or States where grown.
Improved Red	Missouri.
India	Maine, Ohio.
Indian Red	Missouri, Ohio.
Indiana Special	Indiana.
Jersey Red	Tennessee.
Jones' Chaff	Kentucky.
Jones' Prolific	Indiana.
June	Oregon.
Kansas Clubhead	Texas.
Kay's Prolific	Maryland.
Keener	Tennessee.
Kentucky Blue Joint	Michigan.
Kentucky Clayground	Indiana.
Kentucky Hillarde	Ohio.
Kentucky Red	Ohio.
Kentucky White	Kentucky.
Keystone	Ohio.
King	Virginia.
*Kivet	North Carolina.
Keifes	Colorado.
La Crosse	Indiana.
Lamond	Kentucky.
Landflash	Idaho.
Landreth's Longberry	Tennessee.
Late	Georgia.
Late Big Grain	Alabama.
Leader	Pennsylvania.
Little Blood	Indiana.
Little Spring	Tennessee.
Little White	Georgia.
Log Cabin	New York.
Lone Sack	Illinois.
*Lost Nation	Iowa, Maine, Vermont, Wisconsin.
McGee	Missouri, Tennessee.
Mackey	Idaho.
Mammoth Bald	Michigan.
Mammoth Bearded	Alabama.
Manchuria	Ohio.
Manitoba	New York, Tennessee.
Marblehead	Minnesota.
Maryland	Georgia.
May King	Kansas.
Meadow King	North Carolina.
Michigan Gold Standard	Ohio.
Midlenton	Tennessee.
*Minnesota Wonder	Oregon.
Minnesota Chief	Indiana.
Missouri Red	Tennessee.
Monarch	Ohio.
Monitor	Ohio.
Moore	Tennessee, Georgia.

LIST OF UNIDENTIFIED VARIETIES OF WHEAT—Continued.

Name of variety.	State or States where grown.
Morris	North Carolina.
Mortgage	Idaho.
Mountain White	West Virginia.
Muck	Ohio.
Native Spring	New York.
Nelson	Arkansas.
New English	Tennessee.
New Russia	New Mexico.
New York No. 10	Kentucky.
Number 7	New York.
Number 9	Michigan, New York.
Number 12	New York.
Number 16	New York.
Oklahoma Chief	Missouri.
Parker	Kentucky.
Patent Office	Mississippi, Tennessee.
Pearl	Illinois.
Pearl of Harvest	New York.
Pearson's Red	North Carolina.
Peerless	Kentucky, North Carolina, Tennessee.
Pennsylvania Red	Delaware, Kentucky, Maryland, New Jersey, Tennessee.
Phubec	West Virginia.
Premium	Missouri.
Pride of Michigan	Michigan.
Pride of Missouri	New York.
Prize	California, Tennessee.
Purity	West Virginia.
Quacker	Kentucky.
Queen Bess	Michigan.
Rainbow	Alabama.
Red Australian	California.
Red Baldwin	Ohio.
Red Champion	Michigan.
Red Cloud	Missouri.
Red Cure	Oklahoma.
Red Diamond	Pennsylvania.
Red Egyptian	New York.
Red Hackle	Ohio.
Red Imperial	Ohio.
Red Lake	West Virginia.
Red Leader	West Virginia.
Red Monarch	Tennessee, Vermont.
Red No. 2	New York.
Red River	Indiana, Missouri, Ohio, Pennsylvania.
Red River Special	Nebraska, Tennessee.
Red Rust Proof	Mississippi, Tennessee.
Red Tom	Kentucky.
Red Western	Missouri.
Red Willow	Nebraska.
Red Wool	Missouri.

LIST OF UNIDENTIFIED VARIETIES OF WHEAT—Continued.

Name of variety.	State or States where grown.
Reising.....	Pennsylvania.
Reynolds.....	Arkansas.
*Rio Grande.....	Iowa, New York, Wisconsin.
Rock.....	Illinois, Indiana, Kentucky.
Rodger's Red.....	Illinois.
Roll.....	West Virginia.
Royal Cross.....	Missouri.
Rucker.....	Georgia.
Russian Empire.....	Illinois.
Russian Cross.....	Pennsylvania.
Russian Prolific.....	Ohio.
Scot.....	Indiana, Ohio.
Scotland.....	Iowa.
Scrub.....	Georgia.
*Sea Island.....	Illinois, Iowa, Kansas, Missouri, Nebraska.
Shanghai.....	Maryland.
Sheaf Prolific.....	South Carolina.
Shepherd's Special.....	Michigan.
Shoepeg.....	Tennessee.
Silver Hull.....	North Carolina.
Silver Queen.....	Ohio.
Silver Star.....	Tennessee.
Silver Straw.....	North Carolina.
Sink.....	Tennessee.
Smith.....	Oregon.
Smooth Chaff.....	North Carolina.
Snowflake.....	California.
Soft May.....	Wyoming.
Spangler Beardless.....	Pennsylvania.
Spring Giant.....	Washington.
Stevens.....	South Carolina.
Stewart's No. 13.....	Pennsylvania.
Stump.....	Indiana.
Success.....	Ohio.
Sudling.....	Missouri.
Superior.....	Iowa.
Swan.....	Virginia.
Swings White.....	North Carolina.
*Tappahanock.....	Tennessee.
Tennessee Bluestem.....	Mississippi.
Tennessee Red.....	Alabama, Indiana, Kentucky, Missouri, North Carolina.
Texas Red.....	Kentucky, Nebraska, Tennessee.
Thousand Fold.....	New Jersey.
Turner's High Bred.....	Maryland.
Victory.....	Illinois.
Virginia Beauty.....	North Carolina.
Virginia Bluestem.....	South Carolina.
Virginia Golden.....	Oklahoma.
Virginia Red.....	Virginia.
Wabash.....	Indiana.

LIST OF UNIDENTIFIED VARIETIES OF WHEAT—Continued.

Name of variety.	State or States where grown.
Wayside Wonder.....	Delaware.
Webber.....	West Virginia.
Western Three-Mesh.....	Oregon.
White Ball.....	Michigan.
White Bearded.....	Alabama.
White Boodle.....	North Carolina.
White Bronze.....	New York.
White Chaff.....	Illinois, Kansas, Kentucky, Maryland.
White Chaff Mediterranean.....	New York.
White Cross.....	Indiana, Missouri.
White Deal.....	Michigan.
White Diamond.....	Ohio.
White Elephant.....	Michigan.
White Excelsior.....	North Carolina.
White Flint.....	Michigan, West Virginia
White Fultz.....	Kansas, Missouri.
Whitehead.....	Arkansas.
*White Leader.....	West Virginia
White Lily.....	Idaho.
White Lime Stone.....	Kentucky.
White May.....	Georgia, Louisiana, Tennessee.
White Mediterranean.....	West Virginia.
White Mountain.....	Delaware, New Hampshire.
White Plymouth.....	Michigan.
White Poole.....	West Virginia.
White Ray.....	Arkansas.
White Rock.....	Michigan, North Carolina, West Virginia.
White Rose.....	Ohio.
White Valley.....	Oregon.
White Wave.....	Indiana.
Whitlock.....	Tennessee.
Whitney.....	North Carolina.
Williamsburg.....	Maryland.
Winter Proof.....	Illinois.
Winter Queen.....	Delaware, Ohio, Oklahoma.
Wisconsin Pedigree No. 1.....	Illinois, Wisconsin.
Wisconsin No. 5.....	Wisconsin.
World Wonder.....	Kentucky.
Wright.....	Michigan.

Of the wheats in the foregoing list, Boughton, Canada Club, Castillione, Kivet, Lost Nation, Minnesota Wonder, Rio Grande, Sea Island, Tappahannock, and White Leader are known to be distinct varieties or mixtures of wheats here described. Nothing is known concerning the other names.

Boughton and Tappahannock are the same variety, both names being commonly used for many years, but the variety has not been

identified. The history of the variety is given in the Rural New Yorker of 1858 (3), as follows:

The Lynchburg Virginian says: "Seven years ago (1851) Mr. J. L. Boughton (of Tappahannock, Essex County, Va.) found in his field of wheat four heads that had ripened some 15 days earlier than the remainder of his crop. He preserved the grain and sowed it, and continued resowing it every year, until his crop comes in this year at least a month earlier than usual."

Canada Club is a spring wheat and was widely grown from 1850 to 1870. It since has practically disappeared from cultivation in the United States. It is stated by Danielson (76, p. 385) to be the Golden Drop originated by F. F. Hallett, of Brighton, England. De Neven (78, p. 148) reported its use and history in 1854 to be as follows:

The "Canada Club" variety, which is generally regarded among our farmers as the most profitable spring wheat, considering the ease of raising it, brings, together with the "Rio Grande," the highest market price. It was brought to the United States from Canada, where it formerly was extensively cultivated; but not so much now on account of the terrible ravages of the weevil. It was introduced into Canada from France, where it is, at this day, the kind most raised. This wheat is vulgarly known in that country by the name of "Petit blé de mars blanc" (small March white wheat), all kinds of spring wheat being generally designated as "blé de mars," as March is the month in which it is usually sown.

The "Canada Club" is a bald wheat, grows remarkably even and straight. The straw is uncommonly stiff and its height rather below medium, for which reasons it is less liable to be laid low by the winds and storms than any kind of spring wheat with which I am acquainted, a quality of great value to farmers. The flour made from it is not very fine, but good; and the quality heavy.

Castillione is a badly mixed durum spring wheat distributed by Lorenzo Falzone, of Milesville, S. Dak., in 1917. He obtained 2 pounds of seed in Italy and grew it for the first time in South Dakota in 1914, increasing it in 1915 and 1916. As it proved more resistant to stem rust in 1916 than other varieties in his neighborhood, he distributed it as a rust-resistant variety. Experiments have not shown it to be especially resistant, however. The fact that it contains three distinct types makes it objectionable for growing and impossible to classify here. It contains strains having both white and black awns and glabrous and pubescent glumes, which may be either white or yellowish. The kernels of all strains are white (amber).

Kivet is a white-kerneled wheat which has been grown in North Carolina for many years. It was obtained by Blount (47) and grown and reported in 1892 in his New Mexico experiments. It possibly is the same wheat as White Wonder, as both are grown in the same localities.

Lost Nation is an old awnless spring wheat of the northeastern United States, which has now gone out of cultivation. A history of the wheat was recorded in 1878 in the Rural New Yorker as follows:

With regard to this variety of wheat, Doctor Hoskins of Orleans County, Vt., writes us: "I was one of the very first to plant it in Vermont, having, with three others in different parts of the State, four years ago received a quart of it from Rev. Marcus A. Keep, of Dalton, Aroostook County, Me. I got a bushel from the quart, sowed it all and distributed the 26 bushels that grew from it among my neighbors, and now it is the principal wheat in the vicinity."

Minnesota Wonder and Early Wonder are names used for a mixture of Kinney, Huston, and Defiance, grown in the Willamette Valley of Oregon.

Rio Grande is a bearded spring wheat which was reported grown in Wisconsin as early as 1853. Concerning it De Neven (78, p. 148) has recorded the following information:

"The Rio Grande" wheat was introduced among us more recently than the "Canada Club." * * * It was brought into Illinois by an Englishman, a soldier in the Mexican War, who carried from the banks of the Rio Grande a handful in his knapsack and sowed it in his garden, from which my seed was derived. * * * It grows very tall, having the ears furnished with long beards and, altogether, when standing in the field, it strongly resembles the "Black Sea" variety, only the straw is somewhat larger, if not longer.

In 1896 Hays (108, p. 322) discussed its probable value for Minnesota, as follows:

University No. 72, Rio Grande, has been grown by the experiment station for a number of years. It is a medium-sized plant, bearded, chaff is smooth, white, and holds tightly to the berry. The berry has much the same appearance as the Red Fife, but has usually graded one grade below Fife grown beside it. As it is bearded, hardly as good a yielder as Fife and Bluestem, and not able to secure as good grades, this variety will hardly compete with the standard sorts. This wheat at times has seemed especially susceptible to the effects of rust.

Sea Island is a spring wheat which was quite commonly grown in Nebraska during the nineties, but which has now nearly gone out of cultivation. The origin of the variety is undetermined. A sample was obtained from Colorado in 1919, but it was badly mixed, containing at least five distinct types, so its correct identity could not be determined.

White Leader or Early White Leader is a variety listed on the stationery of A. N. Jones, of Newark, Wayne County, N. Y., where he claims to have originated it in 1893. Nothing further is known concerning it.

ESTIMATED ACREAGE OF VARIETIES.

The varietal survey, previously mentioned, has furnished a basis for estimating the actual and percentage acreages of the different varieties (Tables 2 and 3). In compiling Table 2 all estimated percentage acreages from all reports from a county were totaled and the average percentage which each variety represented in the wheat

acreage of the county was determined. The actual number of acres of wheat in each county, as determined by the preliminary reports of the Fourteenth United States Census, were used to compute the estimated number of acres of each variety. The varietal survey and the census data were for the same year, 1919. The estimated acreage of the different varieties in each State (Table 2) and in the United States (Table 3) thus have been determined and a corresponding weighted percentage computed.

In filling out the varietal questionnaires many reporters listed only the most important varieties and grouped the remaining as "others" or else failed to report varieties totaling a full 100 per cent. Other correspondents reported "no wheat" where the census reports showed a small acreage for the county. These undetermined percentages have been carried as "others and not reported" in all computations. The unidentified varieties reported have also been included under that heading.

Most of the crop reporters were not acquainted with the names of varieties of club and durum wheat. Instead of reporting varieties, therefore, these classes of wheat usually were reported merely as "club" and "durum." In tabulating the results these class names are used with the explanation "varieties not reported" in parentheses. The acreage data for club and durum varieties, therefore, are of little value, but the varieties known by the writers to be grown are listed by name in all cases. Where these names were not reported on the survey, the acreage and percentage columns are left blank. For all varieties reported but which have an estimated actual acreage of less than 100 acres or an estimated percentage of less than 0.1 per cent, leaders (dotted lines) are shown in each figure column. The figures following the State names show the number of reports used in computing the averages.

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919.*

[Figures in parentheses following the names of States show the number of reports used in computing the averages.]

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
ALABAMA (223).			ALABAMA—continued.		
Currell.....			Turkey.....		
Flint.....	200	0.6	Others and not reported.....	5,817	17.0
Fulcaster.....	5,700	16.8	Total.....	34,017	100.0
Fultz.....	600	1.8	ARIZONA (41).		
Leap.....			Alaska.....	200	.5
Mealy.....	200	.6	Baart.....	20,100	55.6
Mediterranean.....			Club (varieties not reported)....	6,300	17.4
Poole.....					
Purplestraw.....	18,500	54.4			
Red May.....	3,000	8.8			

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
ARIZONA—continued.			COLORADO (253).		
Defiance.....	400	1.1	Alton.....		
Durum (varieties not reported).....	200	.5	Arnautka.....		
Indian.....	200	.5	Baart.....	100	.....
Little Club.....	500	1.4	Black Winter (emmer).....		
Martin.....	200	.5	Club (varieties not reported).....	2,900	0.2
Marquis.....	300	.8	Colorado No. 50.....	700	.....
Pacific Bluestem.....	600	1.7	Defiance.....	124,000	9.3
Sonora.....	5,700	15.8	Durum (varieties not reported).....	148,000	11.2
Touse.....	100	.3	Haynes Bluestem.....	3,100	.2
Turkey.....	600	1.7	Jones Fife.....	4,600	.3
Others and not reported.....	942	2.2	Kubanka.....	100	.....
Total.....	36,342	100.0	Ladoga.....	6,100	.5
ARKANSAS (274).			Marquis.....	125,200	9.4
Currell.....	2,800	1.1	Pacific Bluestem.....	7,900	.7
Flint.....	3,700	1.4	Palisade.....	1,600	.1
Fulcaster.....	30,400	11.9	Preston.....		
Fultz.....	37,100	14.5	Regenerated Defiance.....		
Gold Drop.....	600	.2	Sonora.....	3,300	.2
Gipsy.....	3,000	1.2	Surprise.....	1,500	.1
Harvest Queen.....	100	.....	Turkey.....	884,300	66.6
Marquis.....	200	.1	Vernal (emmer).....		
Mediterranean.....	24,100	9.4	Others and not reported.....	15,613	1.2
Nigger.....	1,400	.5	Total.....	1,329,013	100.0
Poole.....	1,200	.5	CONNECTICUT (18).		
Purplestraw.....	21,500	8.4	Durum (varieties not reported).....		
Red May.....	63,700	24.9	Goldcoin.....	100	3.6
Red Wave.....	3,300	1.3	Leap.....		
Rice.....	500	.2	Marquis.....	1,000	36.0
Rudy.....	1,300	.5	Purplestraw.....	300	10.8
Turkey.....	14,300	5.6	Red May.....	100	3.6
Walker.....	4,100	1.6	Red Rock.....		
Others and not reported.....	42,908	16.7	Red Wave.....	400	14.4
Total.....	256,208	100.0	Others and not reported.....	876	31.6
CALIFORNIA (205).			Total.....	2,776	100.0
Ala-ka.....			DELAWARE (27).		
Baart.....	116,400	10.7	Currell.....	1,100	.9
Big Club.....	500	.....	Fulcaster.....	18,800	14.9
Bobs.....			Fultz.....	14,100	11.2
Bunyip.....			Fultz-Mediterranean.....	490	.3
Canadian Red.....	300	.....	Gipsy.....	1,700	1.4
Club.....	1,900	.2	Leap.....	12,700	10.1
Club (varieties not reported).....	111,900	10.3	Mediterranean.....	7,700	6.1
Dart.....			Poole.....	1,300	1.3
Defiance.....	26,500	2.4	Red Wave.....	800	.6
Durum (varieties not reported).....	600	.1	Rudy.....	800	.6
Early Defiance.....			Others and not reported.....	66,340	52.6
Frost.....	1,700	.2	Total.....	125,740	100.0
Galzeden.....	18,000	1.7	FLORIDA (8).		
Goldcoin.....			Fulcaster.....		
Hard Federation.....			Fultz.....		
Imbuck.....			Mediterranean.....		
Little Club.....	27,100	2.5	Purplestraw.....	10	38.0
Lynx.....	9,300	.9	Others and not reported.....	16	62.0
Marquis.....	4,700	.4	Total.....	26	100.0
Odessa.....	2,900	.3	GEORGIA (864).		
Pacific Bluestem.....	441,400	40.5	Climax.....		
Purplestraw.....			Currell.....	1,000	.7
Propo.....	19,400	1.8	Dichl-Mediterranean.....	100	.1
Quality.....			Flint.....		
Sed.....			Fulcaster.....	17,700	12.4
Sonora.....	190,600	17.5	Fultz.....	2,100	1.4
Swartout.....	29,300	2.7	Grandprize.....		
Turkey.....	7,200	.7	Leap.....	2,300	1.6
White Federation.....					
White Winter.....	2,000	.2			
Others and not reported.....	79,614	6.9			
Total.....	1,091,314	100.0			

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
GEORGIA—continued.			ILLINOIS—continued.		
Mealy.....	700	0.5	Marquis.....	464,800	11.3
Mediterranean.....	600	.4	Mediterranean.....	261,500	6.4
Poole.....	.....	.....	Nigger.....	29,700	.7
Purplestraw.....	77,400	54.2	Odessa.....	900	.....
Red May.....	34,100	23.9	Poole.....	112,900	2.8
Red Wave.....	.....	.....	Preston.....	23,800	.6
Rice.....	100	.1	Red Clawson.....	2,500	.1
Others and not reported.....	6,789	4.7	Red Fife.....	3,400	.1
Total.....	142,889	100.0	Red May.....	138,200	3.4
IDAHO (251).			Red Rock.....	2,500	.1
Alaska.....	.....	.....	Red Wave.....	142,400	3.5
Allen.....	1,800	.2	Rudy.....	15,300	.4
Baart.....	15,200	1.3	Russian Red.....	23,900	.6
Big Club.....	12,300	1.1	Turkey.....	1,106,200	27.0
Club (varieties not reported).....	44,700	3.9	Valley.....	4,800	.1
Defiance.....	15,400	1.3	Walker.....	3,900	.1
Dicklow.....	159,800	14.0	Others and not reported.....	281,950	6.9
Durum (varieties not reported).....	1,900	.2	Total.....	4,104,950	100.0
Eaton.....	4,300	.4	INDIANA (902).		
Fultz.....	400	.....	China.....	2,000	0.1
Goldcoin.....	92,800	8.1	Climax.....	1,300	.....
Gypsum.....	9,600	.8	Currel.....	28,200	1.0
Hybrid 128.....	1,800	.2	Dawson.....	100	.....
Jenkin.....	21,300	1.9	Diehl-Mediterranean.....	1,400	.1
Jones Fife.....	25,200	2.2	Durum (varieties not reported).....	2,400	.1
Little Club.....	24,600	2.2	Fulcaster.....	35,000	1.2
Lofthouse.....	3,600	.3	Fultz.....	410,700	14.7
Marquis.....	185,400	16.2	Fultz-Mediterranean.....	29,000	1.0
Martin.....	7,400	.6	Gipsy.....	17,500	.6
Mediterranean.....	200	.....	Goens.....	60,800	2.1
Odessa.....	14,500	1.3	Goldcoin.....	2,200	.1
Pacific Bluestem.....	141,600	12.4	Grandprize.....	4,500	.2
Redchaff.....	4,400	.4	Harvest Queen.....	4,700	.2
Red Clawson.....	.....	.....	Jones Fife.....	25,200	.9
Red Fife.....	2,300	.2	Leap.....	2,900	.1
Red Russian.....	38,600	3.4	Mammoth Red.....	700	.....
Regenerated Defiance.....	.....	.....	Marquis.....	11,000	.4
Sonora.....	22,800	2.0	Mealy.....	.....	.....
Surprise.....	5,300	.5	Mediterranean.....	63,900	2.3
Touse.....	2,600	.2	Nigger.....	100,600	3.6
Turkey.....	178,000	15.6	Odessa.....	1,500	.1
White Polish.....	.....	.....	Poole.....	707,600	25.3
Others and not reported.....	103,495	9.1	Prosperity.....	1,800	.1
Total.....	1,141,295	100.0	Red Clawson.....	7,500	.3
ILLINOIS (837).			Red May.....	147,200	5.3
China.....	2,400	.1	Red Rock.....	15,200	.5
Climax.....	7,400	.2	Red Wave.....	369,700	13.2
Currel.....	22,400	.5	Rudy.....	238,100	8.5
Dawson.....	4,900	.1	Russian Red.....	58,500	2.1
Democrat.....	1,700	.....	Turkey.....	128,100	4.6
Diehl-Mediterranean.....	6,200	.1	Valley.....	200	.....
Durum (varieties not reported).....	10,500	.3	Wheedling.....	10,900	.4
Flint.....	6,100	.1	Others and not reported.....	308,257	11.0
Fulcaster.....	105,200	2.5	Total.....	2,798,657	100.0
Fultz.....	991,600	24.1	IOWA (737).		
Fultz-Mediterranean.....	50,000	1.2	Durum (varieties not reported).....	15,400	1.1
Gipsy.....	4,000	.1	Fultz.....	5,300	.4
Goens.....	3,800	.1	Fultz-Mediterranean.....	900	.1
Goldcoin.....	2,000	.....	Harvest Queen.....	400	.....
Grandprize.....	6,400	.1	Haynes Bluestem.....	96,000	4.8
Harvest Queen.....	94,900	2.3	Iowa No. 404.....	13,100	.9
Haynes Bluestem.....	32,600	.8	Iowa No. 1946.....	.....	.....
Humpback.....	4,100	.1	Java.....	4,800	2.8
Illini Chief.....	.....	.....	Jones Fife.....	200	.....
Iowa No. 404.....	900	.....	Marquis.....	402,800	28.0
Java.....	2,600	.1	Mediterranean.....	2,200	.2
Jones Fife.....	126,400	3.1	Odessa.....	500	.....
Leap.....	200	.....	Preston.....	65,100	4.5
Martin.....	.....	.....	Red Fife.....	14,000	1.0

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
IOWA—continued.			KENTUCKY—continued.		
Red May.....	14,000	1.0	Turkey.....	1,200	0.1
Red Wave.....	600	—	Walker.....	3,500	.4
Turkey.....	749,100	52.0	Others and not reported.....	86,532	10.8
Others and not reported.....	53,396	3.2	Total.....	830,732	100.0
Total.....	1,437,796	100.0	LOUISIANA (12).		
KANSAS (1360).			Fultz.....	—	—
Alton.....	8,100	0.1	Fultz-Mediterranean.....	200	11.7
Blackhull.....	—	—	Marquis.....	—	—
Black Winter (emmer).....	—	—	Purplestraw.....	200	11.7
Currell.....	130,200	1.2	Red May.....	—	—
Diehl-Mediterranean.....	62,500	.6	Others and not reported.....	1,314	76.6
Durum (varieties not reported).....	43,200	.4	Total.....	1,714	100.0
Fulcaster.....	111,700	1.0	MAINE (48).		
Fultz.....	334,300	3.0	Durum (varieties not reported).....	—	—
Fultz-Mediterranean.....	900	—	Marquis.....	10,300	71.2
Gipsy.....	2,200	—	Red Fife.....	2,000	13.8
Harvest Queen.....	509,100	4.5	Wellman.....	—	—
Illini Chief.....	9,600	.1	Others and not reported.....	2,164	15.0
Kanred.....	87,200	.8	Total.....	14,464	100.0
Ladoga.....	—	—	MARYLAND (137).		
Marquis.....	3,200	—	China.....	12,500	1.9
Mediterranean.....	78,300	.7	Currell.....	88,300	13.3
Nigger.....	9,400	.1	Diehl-Mediterranean.....	2,000	.3
Odessa.....	3,300	—	Durum (varieties not reported).....	—	—
Palisade.....	25,900	.2	Fulcaster.....	178,200	26.8
Penquite.....	12,000	.1	Fultz.....	117,400	17.7
Poole.....	14,200	.1	Fultz-Mediterranean.....	19,100	2.9
Red Clawson.....	300	—	Leap.....	43,700	6.6
Red May.....	141,100	1.3	Mammoth Red.....	1,400	.2
Red Wave.....	6,700	.1	Marquis.....	200	—
Rupert.....	1,600	—	Mediterranean.....	39,800	6.0
Turkey.....	9,279,700	82.2	Poole.....	11,900	1.8
Valley.....	—	—	Purplestraw.....	13,600	2.0
Vernal (emmer).....	—	—	Red Clawson.....	600	.1
Zimmerman.....	3,000	—	Red Wave.....	9,400	1.4
Others and not reported.....	407,166	3.5	Rudy.....	13,100	2.0
Total.....	11,279,866	100.0	Silversheaf.....	20,400	3.1
KENTUCKY (515).			Others and not reported.....	92,695	13.9
Ashland.....	—	—	Total.....	664,295	100.0
China.....	1,800	.2	MASSACHUSETTS (16).		
Climax.....	1,000	.1	Dawson.....	300	16.0
Currell.....	69,200	8.3	Marquis.....	1,000	53.3
Dawson.....	900	.1	Red Fife.....	100	5.3
Diehl-Mediterranean.....	300	—	Others and not reported.....	476	25.4
Durum (varieties not reported).....	1,000	.1	Total.....	1,876	100.0
Fulcaster.....	97,900	11.8	MICHIGAN (571).		
Fultz.....	279,200	33.6	Dawson.....	54,400	6.1
Fultz-Mediterranean.....	25,700	3.1	Diehl-Mediterranean.....	11,500	1.3
Gipsy.....	100	—	Durum (varieties not reported).....	5,700	.6
Golden Coin.....	1,500	.2	Fulcaster.....	4,900	.6
Golden Cross.....	500	.1	Fultz.....	5,200	.6
Grandprize.....	4,100	.5	Fultz-Mediterranean.....	3,700	.4
Jones Fife.....	7,800	.9	Gipsy.....	3,700	.4
Leap.....	1,700	.2	Goens.....	3,300	.4
Longberry No. 1.....	3,900	.5	Golden Coin.....	133,500	15.1
Martin.....	3,300	.4	Golden Cross.....	400	.1
Mediterranean.....	49,900	6.0	Grandprize.....	—	—
Mealy.....	4,000	.5	Harvest Queen.....	1,100	.1
Nigger.....	500	—	Haynes Bluestem.....	7,000	.8
Odessa.....	9,400	1.1	Jones Fife.....	2,600	.3
Poole.....	100,500	12.1			
Purplestraw.....	400	—			
Red Clawson.....	400	—			
Red May.....	16,100	1.9			
Red Wave.....	34,900	4.2			
Rice.....	7,000	.8			
Rudy.....	5,700	.7			
Rupert.....	100	—			
Russian Red.....	10,700	1.3			

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
MICHIGAN—continued.			MISSOURI—continued.		
Kanred.....	2,800	0.3	Leap.....	1,500	.....
Longberry No. 1.....	.....	.....	Mammoth Red.....	2,200	.....
Mammoth Red.....	400	.....	Martin.....	1,700	.....
Marquis.....	59,300	6.7	Marquis.....	12,800	0.3
Martin.....	2,200	.2	Mealy.....	2,100	.....
Mediterranean.....	8,500	1.0	Mediterranean.....	341,600	7.5
Nigger.....	27,500	3.1	Nigger.....	6,100	.1
Poole.....	22,200	2.5	Odessa.....	7,600	.2
Preston.....	10,600	1.2	Poole.....	172,000	3.8
Prosperity.....	2,000	.2	Prosperity.....	17,100	.4
Red Clawson.....	34,300	3.9	Red Clawson.....	7,100	.2
Red Fife.....	7,600	.9	Red Fife.....	300	.....
Red May.....	9,800	1.1	Red May.....	443,200	9.7
Red Rock.....	195,400	22.1	Russian Red.....	11,900	.3
Red Wave.....	58,700	6.6	Red Wave.....	78,000	1.7
Rudy.....	18,500	2.1	Rudy.....	1,800	.....
Rupert.....	100	.....	Turkey.....	593,000	13.0
Russian Red.....	3,100	.4	Walker.....	4,900	.1
Treadwell.....	1,000	.1	Zimmerman.....	9,600	.2
Turkey.....	7,400	.8	Others and not reported.....	493,358	9.2
Windsor.....	100	.....	Total.....	4,564,458	100.0
Others and not reported.....	176,960	20.0			
Total.....	885,460	100.0	MONTANA (246).		
MINNESOTA (1,008).			Alaska.....	.....	.....
Arnautka.....	.....	.....	Arnautka.....	.....	.....
Dixon.....	.....	.....	Baart.....	.....	.....
Durum (varieties not reported).....	137,300	3.6	Big Club.....	1,500	0.1
Glyndon.....	.....	.....	Champlain.....	3,100	.2
Haynes Bluestem.....	361,800	9.5	Club (varieties not reported).....	10,600	.6
Humpback.....	18,400	.5	Dicklow.....	600	.....
Kubanka.....	.....	.....	Durum (varieties not reported).....	269,300	15.7
Marquis.....	2,175,300	57.4	Fleming.....	100	.....
Mindum.....	.....	.....	Goldcoin.....	104,100	6.1
Minhardi.....	.....	.....	Haynes Bluestem.....	104,100	6.1
Minturki.....	.....	.....	Jones Fife.....	19,300	1.1
Pental.....	300	.....	Kahla.....	4,000	.2
Preston.....	800,700	21.1	Kubanka.....	2,100	.1
Red Fife.....	65,900	1.8	Ladoga.....	900	.....
Red May.....	600	.....	Little Club.....	200	.....
Turkey.....	62,200	1.6	Marquis.....	689,800	40.3
Vernal (emmer).....	.....	.....	Montana No. 36.....	100	.....
White Fife.....	2,400	.....	Pacific Bluestem.....	11,100	.6
Others and not reported.....	168,502	4.5	Peliss.....	1,400	.1
Total.....	3,793,402	100.0	Pentad.....	4,200	.2
MISSISSIPPI (132).			Preston.....	22,800	1.3
Fulcaster.....	300	3.3	Quality.....	.....	.....
Fultz.....	.....	.....	Red Fife.....	55,400	3.2
Mediterranean.....	.....	.....	Red Russian.....	200	.....
Purplestraw.....	2,200	24.2	Regenerated Defiance.....	.....	.....
Red May.....	2,700	29.7	Sonora.....	.....	.....
Turkey.....	.....	.....	Stanley.....	.....	.....
Others and not reported.....	3,883	42.8	Touse.....	100	.....
Total.....	9,083	100.0	Turkey.....	369,900	21.6
MISSOURI (1,009).			Velvet Don.....	600	.....
Climax.....	1,100	.....	Vernal (emmer).....	.....	.....
Currell.....	155,300	3.4	White Polish.....	.....	.....
Dawson.....	500	.....	Others and not reported.....	138,402	8.6
Flint.....	3,800	.1	Total.....	1,709,802	100.0
Fulcaster.....	273,800	6.0	NEBRASKA (971).		
Fultz.....	1,608,900	37.0	Big Frame.....	.....	.....
Fultzo-Mediterranean.....	92,300	2.0	Club (varieties not reported).....	600	.....
Gipsy.....	3,300	.1	Converse.....	4,300	.1
Gold Drop.....	900	.....	Defiance.....	200	.....
Harvest Queen.....	176,400	3.9	Dixon.....	.....	.....
Illini Chief.....	11,200	.2	Durum (varieties not reported).....	205,400	4.9
Jones Fife.....	29,100	.6	Fulcaster.....	800	.....
			Harvest Queen.....	1,400	.....
			Haynes Bluestem.....	28,700	.7
			Humpback.....	300	.....
			Java.....	10,900	.3

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
NEBRASKA—continued.			NEW MEXICO—continued.		
Ladoga.....	10,400	0.2	Pacific Bluestem.....	200	0.1
Marquis.....	179,300	4.2	Regenerated Defiance.....		
Mediterranean.....	1,700	—	Turkey.....	83,100	61.5
Nebraska No. 28.....			Sonora.....	19,800	14.6
Nebraska No. 60.....			White Polish.....	200	.1
Odessa.....	1,200	—	Others and not reported.....	7,185	5.4
Pallsade.....	14,000	.3			
Pentad.....	700	—	Total.....	135,185	100.0
Preston.....	121,000	2.9			
Red Fife.....	9,000	.2	NEW YORK (300).		
Red May.....	2,000	—			
Regenerated Defiance.....			Dawson.....	53,200	11.5
Turkey.....	3,499,000	82.8	Democrat.....	2,300	.5
Velvet Don.....			Diehl-Mediterranean.....	500	.1
Vernal (emmer).....			Durum (varieties not reported).....	700	.2
White Fife.....			Forward.....		
White Polish.....			Fulcaster.....	7,200	1.6
Others and not reported.....	138,882	3.4	Fultz.....	7,000	1.6
Total.....	4,229,782	100.0	Goldcoin.....	222,000	47.9
			Grand prize.....	800	.2
NEVADA (23).			Honor.....		
			Java.....	700	.2
Baart.....	200	.9	Leap.....	300	.1
Chul.....			Longberry No. 1.....	700	.2
Club (varieties not reported).....	3,800	17.3	Martin.....	300	.1
Defiance.....	200	.9	Marquis.....	52,500	11.3
Goldcoin.....	600	2.7	Mediterranean.....	5,700	1.2
Little Club.....	600	2.7	Poole.....	2,200	.5
Pacific Bluestem.....	6,700	30.5	Portage.....	400	.1
Marquis.....	3,000	13.6	Pride of Genesee.....	2,400	.5
Red Fife.....	200	.9	Prosperity.....	7,800	1.7
Sonora.....	800	3.6	Red Clawson.....	4,500	1.0
Touse.....	1,300	5.9	Red Fife.....	6,900	1.5
Turkey.....	1,600	7.3	Red Wave.....	14,600	3.2
Others and not reported.....	2,987	13.7	Rochester.....	500	.1
Total.....	21,987	100.0	Rudy.....	4,400	.1
			Russian Red.....	800	.2
NEW HAMPSHIRE (26).			Silversheaf.....	400	.1
			Turkey.....	800	.2
Marquis.....	1,200	87.8	White Wonder.....	500	.1
Red Fife.....			Others and not reported.....	63,794	14.0
Others and not reported.....	166	12.2	Total.....	463,894	100.0
Total.....	1,366	100.0			
			NORTH CAROLINA (559).		
NEW JERSEY (35).					
			Climax.....		
China.....	200	0.2	Currell.....	22,000	3.6
Diehl-Mediterranean.....			Diehl-Mediterranean.....	300	—
Fulcaster.....	16,800	19.8	Flint.....	32,800	5.3
Fultz.....	3,000	3.5	Fulcaster.....	199,900	32.2
Gipsy.....	200	.2	Fultz.....	18,400	3.0
Goldcoin.....	100	.1	Fultz-Mediterranean.....	7,500	1.2
Leap.....	5,300	6.2	Goldcoin.....	200	—
Marquis.....	300	.4	Greeson.....	5,100	.8
Mediterranean.....	26,900	31.7	Homer.....		
Red Clawson.....	700	.8	Leap.....	153,100	24.7
Red Wave.....	5,600	6.6	Martin.....	100	—
Rochester.....	400	.5	Marquis.....		
Russian Red.....	100	.1	Mealy.....	600	.1
Others and not reported.....	25,293	29.9	Mediterranean.....	5,200	.8
Total.....	81,893	100.0	Oakley.....	1,500	.2
			Poole.....	300	—
NEW MEXICO (82).			Purplestraw.....	86,500	13.9
			Red Clawson.....	100	—
Alaska.....	400	0.3	Red May.....	15,400	2.5
Baart.....	2,800	2.1	Red Wave.....	1,800	.3
Chacama.....			Rice.....	7,300	1.2
Club (varieties not reported).....	400	.3	Rudy.....	300	—
Defiance.....	3,400	2.5	Russian Red.....	2,400	.4
Durum (varieties not reported).....	9,600	7.1	Silversheaf.....	800	.1
Marquis.....	8,100	6.0	Others and not reported.....	59,059	9.7
			Total.....	620,659	100.0

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
NORTH DAKOTA (757).			OKLAHOMA (429).		
Acme.....	-----	-----	Black Winter (emmer).....	-----	-----
Alaska.....	-----	-----	Club (varieties not reported).....	5,800	0.1
Arnautka.....	-----	-----	Currell.....	70,400	1.5
Buford.....	-----	-----	Diehl-Mediterranean.....	2,400	.1
Durum (varieties not reported).....	2,611,500	28.7	Durum (varieties not reported).....	9,000	.2
Chirka.....	-----	-----	Fulcaster.....	322,400	6.8
Glyndon.....	2,000	-----	Fultz.....	157,900	3.3
Haynes Bluestem.....	725,100	8.0	Fultz-Mediterranean.....	9,600	.2
Humpback.....	6,600	.1	Harvest Queen.....	218,200	4.6
Kahla.....	14,700	.2	Kanred.....	10,300	.2
Kota.....	-----	-----	Mediterranean.....	215,800	4.6
Kubanka.....	25,900	.3	Poole.....	700	-----
Kubanka No. 8.....	-----	-----	Purplestraw.....	6,200	.1
Marquis.....	4,274,800	47.0	Quality.....	-----	-----
Monad.....	-----	-----	Red Fife.....	-----	-----
Peliss.....	-----	-----	Red May.....	39,800	.8
Pentad.....	33,500	.4	Red Wave.....	900	-----
Power.....	9,100	.1	Rudy.....	8,500	.2
Preston.....	760,100	8.4	Sibley.....	200	-----
Red Fife.....	526,000	5.8	Turkey.....	3,235,500	68.6
Turkey.....	33,900	.4	Vernal (emmer).....	-----	-----
Vernal (emmer).....	-----	-----	Walker.....	1,800	-----
White Fife.....	-----	-----	Others and not reported.....	404,505	8.7
White Polish.....	-----	-----	Total.....	4,717,905	100.0
Others and not reported.....	74,273	.6			
Total.....	9,098,473	100.0			
OHIO (813).			OREGON (161).		
Currell.....	4,700	.2	Alaska.....	-----	-----
Dawson.....	5,200	.2	Ariette.....	-----	-----
Democrat.....	1,500	.1	Baart.....	39,700	3.7
Diehl-Mediterranean.....	1,600	.1	Big Club.....	3,600	.3
Durum (varieties not reported).....	400	-----	Bluechaff.....	-----	-----
Flint.....	1,000	-----	Clackamas.....	-----	-----
Fulcaster.....	24,000	.8	Club (varieties not reported).....	58,200	5.4
Fultz.....	300,100	10.3	Cox.....	1,000	.1
Fultz-Mediterranean.....	12,800	.4	Dale.....	2,200	.2
Gipsy.....	84,000	2.9	Defiance.....	18,500	1.7
Gladden.....	7,700	.3	Durum (varieties not reported).....	1,000	.1
Goens.....	64,200	2.2	Eaton.....	5,200	.5
Goldcoin.....	74,700	2.6	Folsy.....	41,300	3.8
Golden Cross.....	400	-----	Federation.....	-----	-----
Grandprize.....	5,800	.2	Galgos.....	16,500	1.5
Harvest Queen.....	600	-----	Goldcoin.....	155,500	14.4
Illini Chief.....	500	-----	Hard Federation.....	-----	-----
Jones Fife.....	9,900	.3	Huston.....	22,400	2.1
Leap.....	800	-----	Hybrid 63.....	17,600	1.6
Martin.....	1,200	-----	Hybrid 123.....	1,200	.1
Marquis.....	24,900	.9	Hybrid 128.....	103,300	9.6
Mealy.....	23,300	.8	Jenkin.....	4,500	.4
Mediterranean.....	55,500	1.9	Kahla.....	-----	-----
Nigger.....	103,200	3.5	Kinnev.....	23,400	2.2
Penquite.....	-----	-----	Little Club.....	32,100	3.0
Poole.....	1,133,900	39.2	Martin.....	5,000	.5
Portage.....	4,100	.1	Marquis.....	23,700	2.2
Prosperity.....	11,400	.4	Pacific Bluestem.....	121,700	11.3
Read.....	-----	-----	Prohibition.....	21,600	2.3
Red Clawson.....	10,500	.6	Redchaff.....	22,000	2.0
Red May.....	15,300	.5	Red Fife.....	2,400	.2
Red Rock.....	2,900	.1	Red Russian.....	7,700	.8
Red Wave.....	249,200	8.6	Rink.....	14,400	1.3
Rudy.....	46,200	1.6	Sonora.....	12,600	1.2
Rupert.....	10,300	.4	Squarehead.....	-----	-----
Russian Red.....	34,300	1.2	Surprise.....	1,000	.1
Turkey.....	6,100	.2	Tri-let.....	-----	-----
Trumbull.....	1,900	.1	Turkey.....	142,400	13.2
Valley.....	1,400	-----	White Winter.....	50,700	4.7
Wyandotte.....	700	-----	Wilbur.....	6,700	.6
Others and not reported.....	554,792	19.3	Others and not reported.....	97,947	8.9
Total.....	2,922,592	100.0	Total.....	1,080,047	100.0

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
PENNSYLVANIA (454).			SOUTH DAKOTA—continued.		
Alaska.....	.....	.....	Kahla.....	800	.....
China.....	42,400	3.0	Khapli (emmer).....	.....	.....
Climax.....	6,000	.4	Kubanka.....	22,800	0.6
Currell.....	2,700	.2	Marquis.....	2,385,600	61.1
Dawson.....	2,100	.1	Pentad.....	10,600	.3
Democrat.....	600	.....	Preston.....	401,000	10.3
Diehl-Mediterranean.....	20,200	1.4	Red Fife.....	35,900	.9
Durum (varieties not reported).....	500	.....	Regenerated Defiance.....	.....	.....
Fulcaster.....	335,200	23.4	Turkey.....	56,800	1.5
Fultz.....	236,500	16.6	Vernal (emmer).....	.....	.....
Fultz-Mediterranean.....	22,200	1.6	White Polish.....	.....	.....
Gipsy.....	1,000	.1	Others and not reported.....	171,711	4.5
Goens.....	500	.....	Total.....	33,895,111	100.0
Goldcoin.....	13,700	1.0	TENNESSEE (526).		
Gold Drop.....	400	.....	Currell.....	29,600	4.3
Grandprize.....	14,500	1.1	Dawson.....	1,400	.2
Harvest Queen.....	200	.....	Diehl-Mediterranean.....	4,600	.7
Jones Fife.....	6,100	.4	Durum (varieties not reported).....	100	.....
Leap.....	25,800	1.8	Flint.....	400	.1
Martin.....	1,100	.1	Fulcaster.....	277,900	40.5
Marquis.....	2,600	.2	Fultz.....	95,800	14.0
Mealy.....	17,900	1.2	Fultz-Mediterranean.....	11,100	1.6
Mediterranean.....	132,600	9.3	Gold Drop.....	800	.1
Nigger.....	2,100	.1	Harvest Queen.....	400	.1
Penquite.....	200	.....	Leap.....	23,700	3.5
Poole.....	91,000	6.4	Martin.....	1,600	.2
Portage.....	.....	.....	Marquis.....	.....	.....
Prosperity.....	4,500	.3	Mealy.....	16,600	2.4
Purplestraw.....	.....	.....	Mediterranean.....	23,600	3.4
Red Clawson.....	3,600	.3	Odessa.....	3,700	.5
Red Fife.....	2,400	.2	Poole.....	37,200	5.4
Red May.....	6,100	.4	Purplestraw.....	6,900	1.0
Red Wave.....	107,700	7.5	Red May.....	41,900	6.1
Rudy.....	52,200	3.7	Red Wave.....	1,100	.2
Russian Red.....	7,200	.5	Rice.....	14,800	2.2
Schonacher.....	1,000	.1	Rupert.....	2,200	.3
Silversheaf.....	2,900	.2	Russian Red.....	2,700	.4
Turkey.....	1,900	.1	Turkey.....	500	.1
Others and not reported.....	261,937	18.3	Walker.....	4,500	.7
Total.....	1,429,537	100.0	Others and not reported.....	82,397	12.0
RHODE ISLAND (2).			Total.....	685,497	100.0
Fulcaster.....	.....	.....	TEXAS (692).		
Marquis.....	.....	.....	Arnautka.....	14,400	.6
Mediterranean.....	.....	.....	Baart.....	400	.....
Others and not reported.....	106	100.0	Black Winter (emmer).....	.....	.....
Total.....	106	100.0	Durum (varieties not reported).....	26,000	1.1
SOUTH CAROLINA (295).			Fulcaster.....	43,400	1.8
Currell.....	900	1.4	Fultz.....	22,200	.9
Flint.....	7,300	8.5	Kubanka.....	400	.....
Fulcaster.....	3,100	3.6	Leap.....	.....	.....
Fultz.....	1,500	1.7	Marquis.....	3,100	.1
Leap.....	13,200	15.3	Mediterranean.....	1,331,900	55.5
Mealy.....	.....	.....	Nigger.....	.....	.....
Poole.....	300	.3	Poole.....	300	.....
Purplestraw.....	32,800	38.0	Purplestraw.....	4,200	.2
Red May.....	17,900	20.7	Red May.....	7,000	.3
Silversheaf.....	.....	.....	Resaca.....	.....	.....
Others and not reported.....	9,124	10.5	Russian Red.....	15,000	.6
Total.....	86,124	100.0	Sonora.....	2,400	.1
SOUTH DAKOTA (755).			Turkey.....	813,200	33.9
Acme.....	.....	.....	Vernal (emmer).....	.....	.....
Arnautka.....	.....	.....	Walker.....	1,600	.1
Durum (varieties not reported).....	654,500	16.8	Others and not reported.....	115,879	4.8
Charka.....	600	.....	Total.....	2,401,379	100.0
Glyndon.....	.....	.....	UTAH (126).		
Haynes Bluestem.....	153,900	4.0	Big Chub.....	100	.....
Humpback.....	900	.....	Club (varieties not reported).....	24,300	9.1

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
UTAH—continued.			WASHINGTON—continued.		
Defiance.....	2,500	0.9	Hybrid 123.....	26,900	1.1
Dicklow.....	3,500	1.3	Hybrid 128.....	184,000	7.4
Durum (varieties not reported).....	100	..	Hybrid 143.....	49,500	2.0
Genesee Giant.....	1,600	.6	Jenkin.....	40,700	1.6
Goldcoin.....	22,700	8.5	Jones Fife.....	215,900	8.7
Indian.....	..	..	Little Club.....	19,200	.8
Jones Fife.....	3,100	1.2	Marquis.....	231,700	9.3
Kofod.....	7,900	2.9	Martin.....	13,700	.5
Little Club.....	1,800	.7	Mayview.....	..	..
Lofthouse.....	2,900	1.1	Mexican Bluestem.....	..	..
Martin.....	..	..	Pacific Bluestem.....	620,500	24.9
Marquis.....	15,600	5.8	Redchaff.....	13,600	.5
Odessa.....	8,500	3.2	Red Russian.....	108,400	4.3
Pacific Bluestem.....	11,700	4.4	Schlanstedt.....	..	..
Red Fife.....	..	..	Sol.....	800	..
Sevier.....	900	.3	Sonora.....	..	..
Silvercoin.....	1,600	.6	Squareheads Master.....	..	..
Sonora.....	8,100	3.0	Surprise.....	..	..
Surprise.....	23,400	8.7	Titanic.....	..	..
Touse.....	18,600	6.9	Triplet.....	..	..
Turkey.....	83,300	31.0	Turkey.....	190,400	7.6
Others and not reported.....	26,257	9.8	Winter Alaska.....	..	..
Total.....	268,457	100.0	Winter Bluestem.....	..	..
			Others and not reported.....	91,660	3.9
VERMONT (32).			Total.....	2,494,160	100.0
Ghirka.....	200	1.8	WEST VIRGINIA (307).		
Marquis.....	5,600	49.7	China.....	..	..
Red Fife.....	400	3.5	Climax.....	..	..
Others and not reported.....	5,076	45.0	Currell.....	500	0.2
Total.....	11,276	100.0	Dawson.....	300	.1
VIRGINIA (548).			Democrat.....	..	..
China.....	2,600	0.3	Diehl-Mediterranean.....	2,100	.7
Currell.....	15,700	1.6	Durum (varieties not reported).....	100	..
Dawson.....	800	.1	Flint.....	400	.1
Diehl-Mediterranean.....	1,400	.1	Fulcaster.....	86,800	29.1
Flint.....	41,500	4.2	Fultz.....	47,900	16.1
Fulcaster.....	378,300	38.1	Fultz-Mediterranean.....	14,100	4.7
Fultz.....	103,800	10.5	Gipsy.....	100	..
Fultz-Mediterranean.....	6,400	.6	Goldcoin.....	1,000	.3
Gipsy.....	1,700	.2	Harvest Queen.....	100	..
Goldcoin.....	700	.1	Jones Fife.....	500	.2
Jones Fife.....	200	..	Leap.....	9,300	3.1
Leap.....	226,600	22.7	Marquis.....	200	.1
Mammoth Red.....	..	..	Mealy.....	100	..
Mediterranean.....	61,500	6.3	Mediterranean.....	31,400	10.5
Poole.....	4,700	.5	Nigger.....	100	..
Purplestraw.....	3,100	.3	Poole.....	39,000	13.1
Red May.....	1,700	.2	Prosperity.....	1,400	.5
Red Wave.....	11,500	1.2	Red Clawson.....	1,900	.6
Rice.....	200	..	Red May.....	1,500	.5
Rudy.....	1,200	.1	Red Wave.....	17,800	.6
Russian Red.....	1,400	.1	Rice.....	1,000	.3
Silversheaf.....	..	..	Rudy.....	500	.2
Turkey.....	1,100	.1	Russian Red.....	100	..
Others and not reported.....	126,161	12.7	Silversheaf.....	10,400	3.5
Total.....	992,261	100.0	Turkey.....	..	..
			White Wonder.....	200	.1
WASHINGTON (257).			Others not reported.....	29,236	15.4
Allen.....	13,400	0.5	Total.....	298,036	100.0
Arcadian.....	..	..	WISCONSIN (560).		
Baart.....	305,600	12.2	Bacsk.....	900	.2
Big Club.....	3,700	.1	Dawson.....	1,400	.3
Black Winter (emmer).....	..	..	Dixon.....	..	..
Club (varieties not reported).....	112,500	4.5	Durum (varieties not reported).....	12,100	2.3
Coppel.....	4,800	.2	Fultz.....	2,100	.4
Dale.....	..	..	Goldcoin.....	400	.1
Durum (varieties not reported).....	1,300	.1	Haynes Bluestem.....	40,600	7.7
Goldcoin.....	225,500	9.0	Humpback.....	1,600	.3
Hybrid 63.....	15,600	.6	Iowa No. 404.....	100	..
Hybrid 108.....	4,800	.2	Java.....	..	..
			Marquis.....	313,400	59.2
			Odessa.....	200	..

TABLE 2.—*Estimate of actual and percentage acreages of wheat varieties grown in the several States in 1919—Continued.*

State and variety.	Area grown.		State and variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
WISCONSIN—continued.			WYOMING—continued.		
Prelude.....	2,700	0.5	Durum (varieties not reported).....	42,500	24.0
Preston.....	26,800	5.1	Erivan.....		
Red Clawson.....	900	.2	Ghirka.....		
Red Fife.....	13,300	2.5	Goldcoin.....		
Red May.....	3,500	.7	Haynes Bluestem.....	4,900	2.8
Red Wave.....	600	.1	John Brown.....		
Turkey.....	39,600	7.5	Jones Fife.....		
Wisconsin Pedigree No. 2.....	6,900	1.3	Kubanka.....		
Others not reported.....	62,645	11.6	Ladoga.....	3,400	1.9
Total.....	529,745	100.0	Marquis.....	61,100	34.5
WYOMING (105).			Odessa.....	100	
Acme.....			Peliss.....	500	.3
Alton.....			Preston.....	1,300	.7
Arnautka.....			Red Fife.....	2,100	1.2
Black Winter (emmer).....			Regenerated Defiance.....		
Bufum No. 17.....			Sonora.....		
Champlain.....	1,200	.7	Surprise.....	400	.2
Club (varieties not reported).....	1,600	.9	Touse.....	100	
Converse.....			Turkey.....	27,800	15.7
Defiance.....	3,300	1.9	Vernal (emmer).....		
Dicklow.....	700	.4	White Polish.....		
			Others not reported.....	25,967	14.8
			Total.....	176,967	100.0

TABLE 3.—*Estimated actual and percentage acreages of wheat varieties as shown by 18,539 reports for the entire United States.*

Variety.	Area grown.		Variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
Acme.....			Dart.....		
Alaska.....	600		Dawson.....	125,500	0.17
Allen.....	15,200	0.02	Defiance.....	194,400	.27
Alstroum (spelt).....			Democrat.....	6,100	.01
Alton.....	8,100	.01	Diamond Grit.....		
Areadian.....			Dicklow.....	164,600	.23
Ariste.....			Diehl-Mediterranean.....	114,700	.16
Arnautka.....	14,400	.02	Dixon.....		
Ashland.....			Durum (varieties not reported).....	4,201,400	5.77
Baarl.....	500,500	.69	Early Defiance.....		
Baaska.....	900		Early Red Fife.....		
Bearded (spelt).....			Eaton.....	9,500	.01
Bearded Winter Fife.....			Einkorn.....		
Belogolma.....			Emerald.....		
Big Club.....	21,700	.03	Erivan.....		
Big Frame.....			Federation.....		
Blackchull.....			Fleming.....		
Black Winter (emmer).....			Flint.....	97,200	.13
Bluechaff.....			Foisy.....	41,300	.06
Bola.....			Frutos.....	1,700	
Bufum No. 17.....			Fulcaster.....	2,576,500	3.54
Canadlan Red.....	300		Fultz.....	4,801,100	6.59
Challenge.....			Fultz-Mediterranean.....	287,900	.40
Champlain.....	4,300	.01	Galgalos.....	34,500	.05
China.....	63,900	.09	Genesee Giant.....	1,600	
Club.....	1,900		Ghirka.....	800	
Clarkman.....			Gipsy.....	122,500	.17
China.....	16,800	.02	Gladen.....	7,700	.01
Club (varieties not reported).....	181,700	.66	Gluton.....		
Colorado No. 50.....	3,300		Glyndon.....	2,000	
Converse.....	1,300	.01	Goens.....	132,600	.18
Coppa.....	4,800	.01	Goldcoin.....	947,100	1.30
Cox.....	1,000		Gold Drop.....	1,600	
Currell.....	645,000	.89	Golden Ball.....		
Dakota.....			Golden Cross.....	900	
Dale.....	2,200		Grandprize.....	34,100	.05
			Greson.....	5,100	.01
			Gypsum.....	9,600	.01

TABLE 3.—*Estimated actual and percentage acreage of wheat varieties as shown by 18,539 reports for the entire United States—Continued.*

Variety.	Area grown.		Variety.	Area grown.	
	Acres.	Per cent.		Acres.	Per cent.
Hard Federation.....			Preston.....	2,233,200	3.06
Harvest Queen.....	1,007,600	1.33	Pride of Genesee.....	2,400	.....
Haynes Bluestem.....	1,530,800	2.10	Prohibition.....	24,600	.03
Homer.....			Propo.....	19,400	.03
Honor.....			Prosperity.....	46,000	.06
Humpback.....	31,900	.04	Purplestraw.....	273,800	.38
Huron.....			Quality.....		
Hussar.....			Read.....		
Huston.....	22,400	.03	Red Bobs.....		
Hybrid 60.....			Redchaff.....	40,000	.05
Hybrid 63.....	33,200	.05	Red Chief.....		
Hybrid 108.....	4,800	.01	Red Clawson.....	80,900	.11
Hybrid 123.....	28,100	.04	Red Fife.....	750,000	1.03
Hybrid 128.....	259,900	.36	Red May.....	1,165,900	1.60
Hybrid 143.....	49,500	.07	Red Rock.....	216,000	.30
Illini Chief.....	21,300	.03	Red Russian.....	154,900	.22
Imperial Amber.....			Red Wave.....	1,132,400	1.55
Indian.....	200	.....	Red Winter (spelt).....		
Iowa No. 404.....	14,100	.02	Regenerated Defiance.....		
Iowa No. 1946.....			Rejaca.....	2,400	.....
Java.....	55,000	.08	Rice.....	30,900	.04
Jonkin.....	66,500	.09	Rink.....	14,400	.02
John Brown.....			Rochester.....	900	.....
Jones Fife.....	476,100	.65	Ruby.....		
Jumbuck.....			Ruddy.....		
Kahla.....	19,500	.03	Rudy.....	399,400	.55
Kanred.....	97,500	.13	Rupert.....	14,200	.02
Khaphi (emmer).....			Rural New Yorker No. 6.....		
Kinney.....	23,400	.03	Rural New Yorker No. 57.....		
Kitchener.....			Russian.....		
Kofod.....	7,900	.01	Russian Red.....	172,000	.24
Kota.....			Rystring.....		
Kubanka.....	52,300	.07	Satisfaction.....		
Kubanka No. 8.....			Schlandstedt.....		
Ladoga.....	20,800	.03	Schonacher.....	1,000	.....
Laramie.....			Seneca Chief.....		
Leap.....	513,100	.70	Sevier.....	900	.....
Link.....			Sibley.....	200	.....
Little Club.....	106,100	.15	Silvercoin.....	1,600	.....
Lofthouse.....	6,500	.01	Silversheaf.....	34,900	.05
Longberry No. 1.....	4,600	.01	Sol.....	800	.....
Lynn.....	9,300	.01	Sonora.....	243,900	.33
Mammoth Amber.....			Squarehead.....		
Mammoth Red.....	3,600	.....	Squareheads Master.....		
Marouani.....			Stanley.....		
Marquis.....	11,825,200	16.24	Surprise.....	60,900	.08
Martin.....	37,800	.05	Talimka.....		
Mayview.....			Titanic.....		
Mealy.....	65,500	.09	Touse.....	20,200	.03
Mediterranean.....	2,558,900	3.51	Treadwell.....		
Mexican Bluestem.....			Triplet.....		
Mindum.....			Trumbull.....	1,900	.....
Minhardi.....			Turkey.....	21,588,300	29.65
Minturki.....			Valley.....	5,200	.01
Monad.....			Velvet Don.....	600	.....
Montana No. 36.....	100	.....	Vernal (emmer).....		
Nebraska No. 28.....			Virginia.....		
Nebraska No. 60.....			Walker.....	24,300	.03
New Amber Longberry.....			Wellman.....		
New Zealand.....			Wheeding.....	10,900	.01
Nigger.....	280,600	.39	White Federation.....		
Norka.....			White Fife.....	2,400	.....
Oakley.....	1,500	.....	White Polish.....	200	.....
Oatka Chief.....			White Spring (spelt).....		
Odessa.....	54,200	.07	White Winter.....	52,700	.07
Ontario Wonder.....			White Wonder.....	700	.....
Pacific Bluestem.....	1,363,400	1.87	Wilbur.....	6,700	.01
Palisade.....	41,500	.06	Windsor.....	100	.....
Peliss.....	1,900	.....	Winter Alaska.....		
Penquite.....	12,200	.02	Winter Bluestem.....		
Pentad.....	50,800	.07	Winter Chief.....		
Pesterboden.....			Wisconsin Pedigree No. 2.....	6,900	.01
Peterson.....			Wisconsin Pedigree No. 40.....		
Pilcrow.....			Wyandotte.....	700	.....
Pioneer.....			Yaroslav.....		
Poole.....	2,453,400	3.37	Zimmerman.....	12,600	.02
Portage.....	4,500	.01	Others and not reported.....	4,977,100	6.84
Power.....	9,100	.01			
Prelude.....	2,700		Total.....	72,801,614	100.0

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INDEX TO VARIETIES AND SYNONYMS.

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³²The Latin names are indexed here for the convenience of those familiar with the classifications of Alefeld, Koernicke and Werner, and others, and not as representing the conclusions of the writers.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1075



Washington, D. C.

July 13, 1922

THE WHIPPING QUALITY OF CREAM.

By C. J. BABCOCK, *Assistant Market Milk Specialist, Dairy Division, Bureau of Animal Industry.*

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FACTORS INFLUENCING WHIPPING QUALITY.

The increasing use of whipped cream, both commercially and in the home, has brought with it a demand for greater knowledge concerning the factors which influence the whipping qualities of cream. It is a subject which has received but little attention. Some reports have been published closely related to the subject but dealing mostly with the effect of adding different substances to the cream and the effect of butterfat content and acidity upon its whipping quality. No accurate means of comparison were employed. Neither was information furnished to the housewife or confectioner as to the best kind of cream to purchase for whipping, nor to the dealer as to the kind of cream he should endeavor to supply in order to assure satisfaction among his customers.

Whipped cream is a valuable food. It is generally considered an appetizing delicacy only and is used as the basis of many desserts, or to garnish, improve, or extend others; but when thus used it increases the food value of the dish.

It is not the aim of this bulletin to explain how to whip cream or how to make cream whip. Its object is to show the whipping quality of cream, in order that both dealers and purchasers may know what is to be desired as a whipping cream.

There are many factors which influence the whipping quality of cream, but it is impossible to discuss them in the order of their importance, because one factor is sufficient to render what would otherwise be an excellent whipping cream useless for whipping purposes. The most important factors are: Kind of cream, age, butterfat content, and temperature.

EXPERIMENTAL PROCEDURE.

The same method of whipping was followed throughout this experiment. One hundred cubic centimeters of cream were placed in a 600 c. c. beaker, which was put in a dish and surrounded with ice to keep the temperature 45° F. or below (except when determining the effect of temperature upon the whipping quality). The cream was then whipped with an ordinary "Dover" egg beater. As this beater is operated by hand, it is impossible to determine the speed accurately. Approximately, however, 200 revolutions per minute of the handle were made, which gave a speed of 1,000 revolutions per minute of the whipping blades. All factors relating to the method of whipping, quantity whipped, and temperature remained constant throughout the experiment, so that any change in the whipping quality was due to some other factor or factors—not to a change in the method of procedure.

The acidity of the cream was determined by titrating with tenth-normal alkali, phenolphthalein being used as the indicator.

The time recorded in the various tables is the time of continuous whipping required to obtain the maximum whip, except in cases where the cream failed to whip; in such cases the maximum stiffness remained the same, or so nearly the same that it was impossible to determine when the maximum was reached. In all cases the cream was whipped for a longer time than recorded, in order to be certain that the maximum whip had been obtained.

METHOD OF COMPARING STIFFNESS OF WHIPPED CREAM.

In order to determine the relative stiffness of different samples of whipped cream it is necessary to have some device that will measure comparative stiffness. The methods usually employed for measuring viscosity are as a rule too complicated to admit of practical application.

The following simple method will enable any one to test the stiffness of different whipped creams very satisfactorily. It is, however, purely a relative measure intended for direct comparison of different creams and the determinations are not comparable with those obtained on the basis of other standards.

The apparatus is in the form of a balance. (Fig. 1.) The right arm of the balance is divided into 60 equal spaces, zero being at the

end, and is provided with a sliding weight. To the left arm a metal disk is suspended of such weight as to form a balance when the sliding weight is at zero. For each space that the sliding weight is moved the pressure exerted increases approximately 1 gram per square inch. The scale reading used throughout this bulletin may be interpreted as the approximate pressure per square inch in grams required to displace the cream. The pressure required to force the disk into the whipped cream was determined and used as a measure of the stiffness or quality of the whips.

The following descriptions may be applied to the various scale readings:

Scale reading.	Description.
Below 6.....	Failed to whip.
7 to 12.....	Very poor whip.
13 to 15.....	Poor whip.
16 to 20.....	Fair whip.
21 to 24.....	Satisfactory whip.
25 to 30.....	Good whip.
31 to 35.....	Very good whip.
36 and above.....	Excellent whip.

An idea of the comparative scale readings can be obtained by referring to Figures 2 to 6, inclusive, which show whipped creams of various qualities.

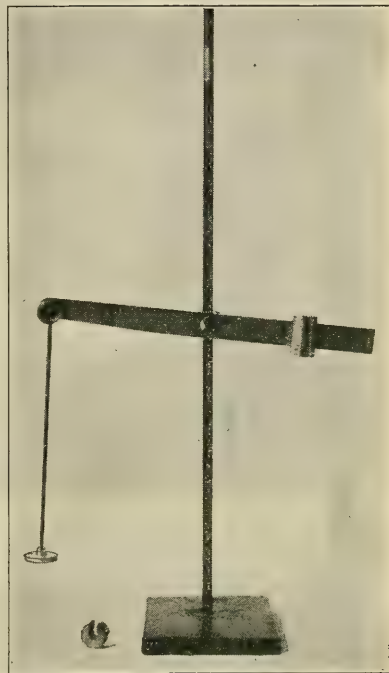


FIG. 1.—Balance for determining the relative stiffness of whipped creams.

RELATION OF VARIOUS FACTORS TO WHIPPING QUALITY.

Cream may be divided into four classes—raw cream, pasteurized cream, homogenized raw cream, and homogenized pasteurized cream. Homogenized raw cream is seldom found on the market.

RAW CREAM.

For whipping purposes raw cream ranked first. It whipped under more adverse conditions than any of the other three, and if it is of good quality, from a sanitary and health standpoint, its use for whipping purposes is highly recommendable.

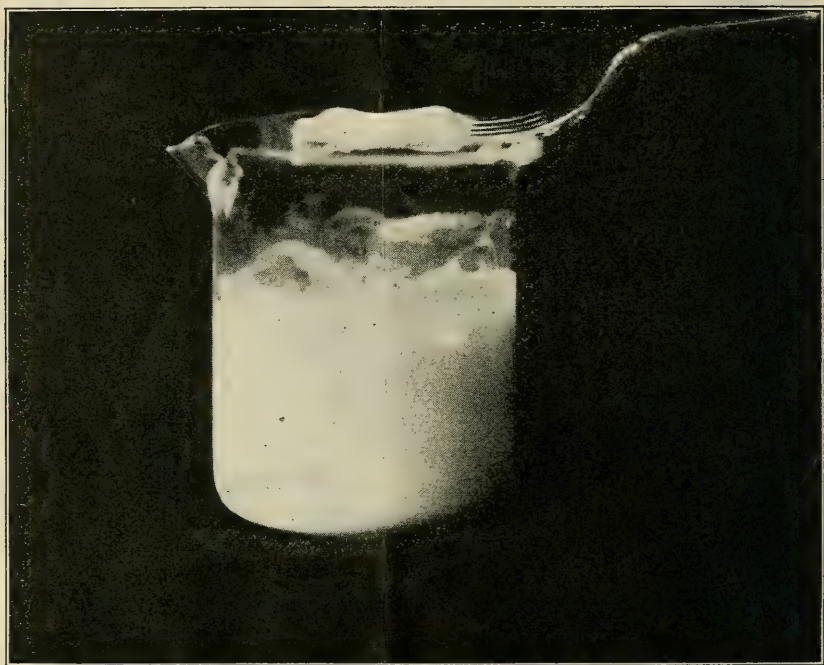


FIG. 2.—Whipped cream with scale of stiffness reading of 8.

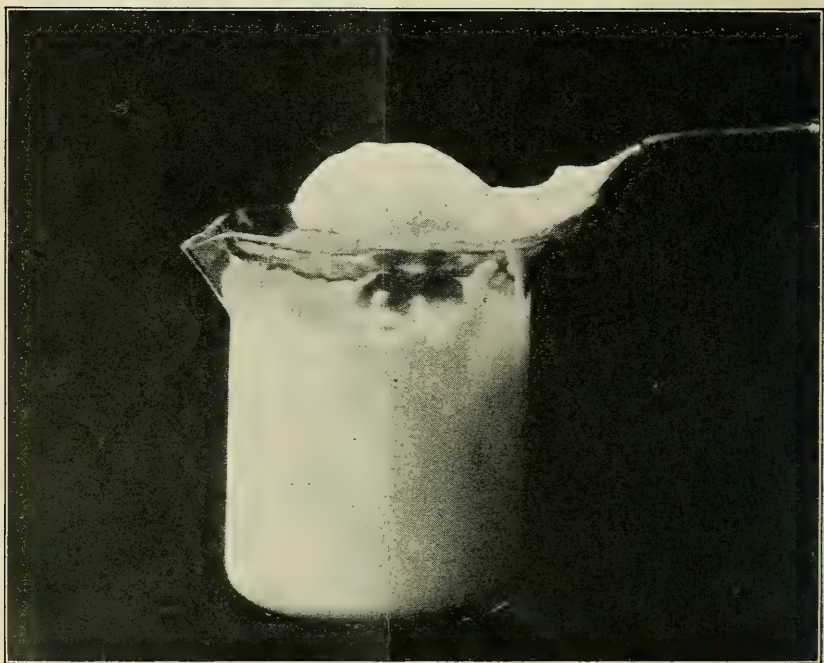


FIG. 3.—Whipped cream with scale of stiffness reading of 20.



FIG. 4.—Whipped cream with scale of stiffness reading of 30.



FIG. 5.—Whipped cream with scale of stiffness reading of 40.



FIG. 6.—Whipped cream with scale of stiffness reading of 50.

TABLE 1.—*Effect of age on whipping quality of raw cream.*

20 PER CENT CREAM.

Age.	Acidity.		Average time of whip- ping.	Scale of stiffness.
	High.	Low.		
<i>Hours.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Minutes.</i>	
2	0.121	0.090	15	4
24	.153	.123	10	8
48	.156	.126	10	12
72	.211	.126	8	16
84	.218	.135	8	20
96	.218	.144	6	24
120	.238	.157	6	26

22 PER CENT CREAM.

2	0.121	0.090	15	4
6	.121	.117	15	8
12	.139	.117	12	12
24	.139	.123	10	20
48	.168	.135	8	26
72	.144	.127	7	30
96	.200	.144	6	32
120	.243	.154	6	32

25 PER CENT CREAM.

2	0.121	0.090	15	6
6	.121	.111	12	16
24	.153	.117	8	24
48	.162	.117	6	29
72	.171	.135	6	34
96	.200	.144	5	36
120	.250	.158	5	36

27 PER CENT CREAM.

2	0.121	0.090	10	12
6	.121	.111	8	20
12	.134	.111	7	28
24	.153	.117	6	32
48	.162	.117	5	38
72	.171	.138	4	44
96	.200	.144	3	44
120	.250	.158	3	44

30 PER CENT CREAM.

2	0.121	0.090	8	20
6	.121	.111	6	40
12	.134	.111	5	44
24	.153	.117	4	48
48	.162	.117	3	52
72	.171	.138	2	52
96	.200	.144	2	52
120	.250	.158	2	52

PASTEURIZATION.

Pasteurized cream ranks next to raw cream for whipping purposes. Although pasteurization is slightly detrimental to the whipping quality, this disadvantage often is more than counterbalanced by the assured safety from the health standpoint from the use of such cream.

A study of Figure 7 and a comparative study of Tables 1 and 2 show the influence of pasteurization on the whipping quality of cream. Practically all the results from which these tables were compiled were obtained from samples of the same cream, a part of which

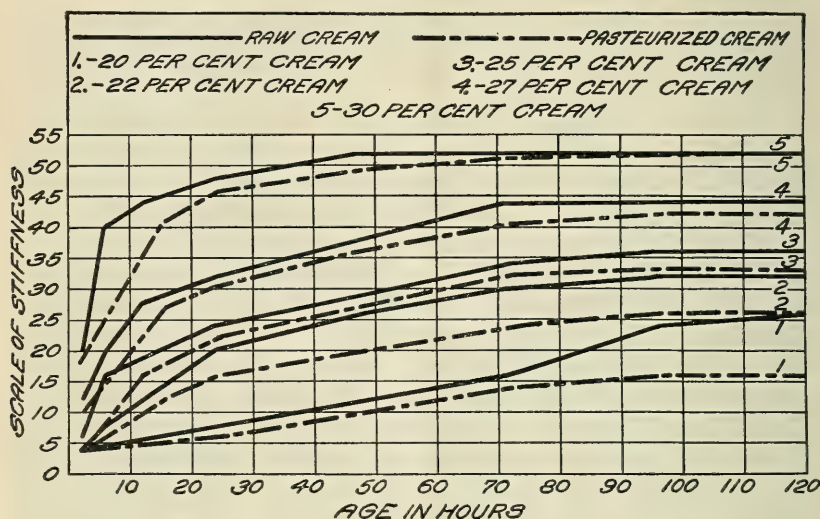


FIG. 7.—Effect of pasteurization on whipping quality of cream.

was pasteurized at 145° F. for 30 minutes. Both the pasteurized and the raw cream were aged under the same conditions, so that any difference in the whipping quality was due to pasteurization.

Pasteurized cream requires greater aging to obtain the maximum whip than raw cream, all other conditions being identical. In the case of cream containing less than 30 per cent butterfat the maximum whip does not equal the maximum for raw cream. It was impossible to obtain a satisfactory whip with the 20 per cent pasteurized cream, whereas with the 20 per cent raw cream a satisfactory whip was obtained after 96 hours of aging. However, it is only necessary to use pasteurized cream with a slightly higher butterfat content to obtain as good a whip as can be obtained from raw cream.

TABLE 2.—*Effect of age on whipping quality of pasteurized cream.*

20 PER CENT CREAM.

Age.	Acidity.		Average time of whipping.	Scale of stiffness.
	High.	Low.		
<i>Hours.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Minutes.</i>	
2	0.134	0.112	15	4
15	.144	.112	15	5
24	.148	.117	12	6
48	.158	.126	12	10
72	.185	.130	10	14
96	.190	.144	8	16
120	.200	.153	8	16

22 PER CENT CREAM.

2	0.103	0.090	15	4
15	.117	.111	12	12
24	.144	.121	10	16
48	.148	.127	10	20
72	.170	.132	8	24
96	.178	.135	8	26
120	.200	.135	8	26

25 PER CENT CREAM.

2	0.111	0.090	10	4
6	.117	.108	10	8
12	.117	.108	10	16
24	.143	.121	8	22
48	.148	.125	8	27
72	.173	.130	6	32
96	.185	.137	5	33
120	.200	.143	5	33

27 PER CENT CREAM.

2	0.111	0.090	10	10
15	.121	.117	7	26
24	.143	.121	6	30
48	.148	.125	6	36
72	.173	.130	5	40
96	.185	.137	4	42
120	.200	.143	4	42

30 PER CENT CREAM.

2	0.111	0.090	8	18
15	.117	.111	5	40
24	.143	.121	5	45
48	.148	.125	4	49
72	.173	.130	3	51
96	.185	.137	3	52
120	.200	.147	3	52

HOMOGENIZATION.

It is undesirable to homogenize cream if it is to be used for whipping purposes. The breaking up of the fat globules by homogenization gives the cream a heavy appearance so that one would think it would be excellent for whipping purposes. But the breaking up of the fat globules also destroys the ability of the cream to incorporate air, and thus impairs its whipping quality. The more thoroughly the fat globules are broken up, or, in other words, the higher the homogenizing pressure, the less the value of the cream for whipping purposes.

Effect of homogenizing.—The detrimental effect of homogenization may be seen by a comparative study of Tables 1 and 3 and in Figure 8. In all cases a sample of the raw cream was whipped both

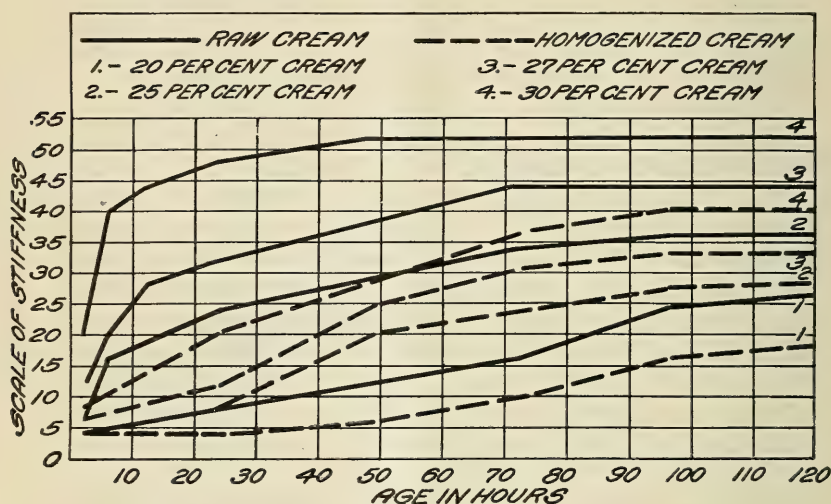


FIG. 8.—Effect of homogenizing at 3,000 pounds' pressure on whipping quality of cream.

before and after homogenizing in order to determine its effect on the whipping quality of the cream.

Figure 8 and Table 3 show that only a fair whip can be obtained from 20 per cent homogenized cream, while 25 per cent homogenized cream gives a satisfactory whip which is only 2 points higher on the scale of stiffness than a whip from 20 per cent raw cream. Thirty per cent homogenized cream gives a whip midway in quality between the 25 per cent and 27 per cent raw creams. In other words, a 20 per cent raw cream is nearly equal to a 25 per cent homogenized cream, and a 27 per cent raw cream is considerably better than a 30 per cent homogenized cream for whipping purposes. Furthermore, the average time required to whip homogenized cream was much greater than that required for raw cream.

A comparative study of Tables 1 and 2 with Table 3 reveals the fact that for whipping purposes homogenized cream comes nearer equaling pasteurized cream than it does raw cream. Homogenization, however, has a more detrimental effect than pasteurization upon the whipping quality of cream. In all cases except that of the 20 per cent grade, pasteurized cream far excelled homogenized cream for whipping.

TABLE 3.—*Effect of age on whipping quality of raw homogenized cream.*

20 PER CENT CREAM.

Age.	Acidity.		Average time of whipping.	Scale of stiffness.
	High.	Low.		
<i>Hours.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Minutes.</i>	
2	0.117	0.111	15	4
24	.143	.121	15	4
48	.175	.143	12	6
72	.195	.176	12	10
96	.200	.196	10	16
120	.247	.200	10	18
25 PER CENT CREAM.				
2	0.121	0.117	15	4
24	.153	.125	12	8
48	.181	.156	10	20
72	.195	.184	9	24
96	.217	.197	9	27
120	.243	.200	7	28
27 PER CENT CREAM.				
2	0.121	0.117	15	6
24	.153	.121	12	12
48	.180	.153	10	24
72	.196	.180	9	30
96	.200	.196	7	33
120	.236	.200	7	33
30 PER CENT CREAM.				
2	0.121	0.117	15	8
24	.153	.121	12	20
48	.180	.153	10	28
72	.196	.180	9	36
96	.200	.196	7	40
120	.236	.200	7	40

HOMOGENIZING PRESSURE.

The effect of homogenizing cream at different pressures is shown in Figure 9 and Table 4, which were compiled from tests of samples of the same cream; that is, the sample receiving no pressure was taken before homogenizing and the remaining samples were obtained at various pressures, so that any difference in whipping quality was due to homogenizing.

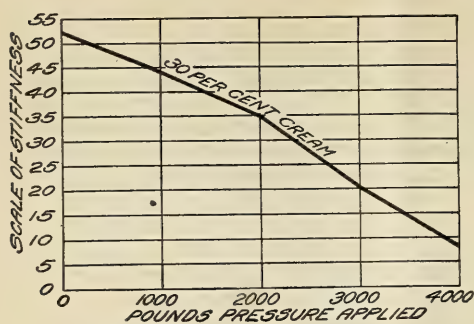


FIG. 9.—Relation of homogenizing pressure to whipping quality of cream.

The whipping quality of cream is inversely proportional to the homogenizing pressure, i. e., an increase in pressure produces a decrease in the whipping quality to such an extent that raw cream which will give a whip with a scale reading of 52 fails to whip when homogenized at 4,000 pounds' pressure. It is also

true that as the quality of the whip decreases the time required to obtain the maximum whip increases.

TABLE 4.—Relation of homogenizing pressure to whipping quality of cream.

Pressure.	Average time of whipping.	Scale of stiffness.
Pounds.	Minutes.	
0	3	52
1,000	3	44
2,000	8	35
3,000	12	20
4,000	15	8

COMBINED PASTEURIZING AND HOMOGENIZING.

Pasteurizing at 145° F. and homogenizing at 3,000 pounds' pressure, together, have a detrimental effect upon the whipping quality

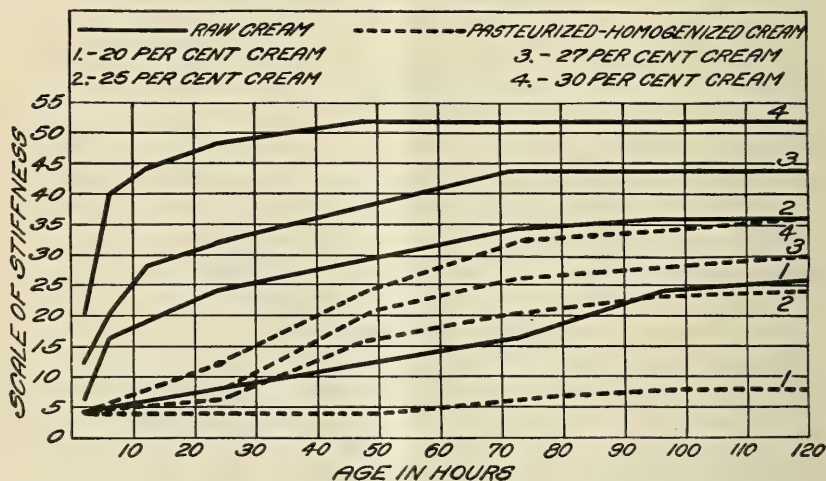


FIG. 10.—Effect of pasteurizing and homogenizing combined on whipping quality of cream.

of cream equal to the sum of the detrimental effects produced by the processes separately, when compared with raw cream.

The effect is such that it is impossible to obtain even a fair whip from such cream containing less than 25 per cent butterfat. Twenty per cent cream failed to whip, and 30 per cent cream gave a maximum whip equal only to a 25 per cent raw cream. (See Fig. 10 and compare Tables 1 and 3 with Table 5.)

TABLE 5.—*Effect of age on whipping quality of pasteurized-homogenized cream.*

Age.	Acidity.		Average time of whipping.	Scale of stiffness.
	High.	Low.		
<i>Hours.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Minutes.</i>	
2	0.111	0.090	15	4
24	.117	.111	15	4
48	.143	.121	15	4
72	.148	.125	15	6
96	.173	.130	12	8
120	.200	.161	12	8
25 PER CENT CREAM.				
2	0.117	0.111	15	4
24	.121	.117	12	6
48	.132	.121	12	16
72	.152	.136	10	20
96	.176	.157	9	23
120	.200	.180	9	24
27 PER CENT CREAM.				
2	0.117	0.111	15	4
24	.121	.117	12	8
48	.136	.121	11	20
72	.157	.136	10	26
96	.180	.157	9	28
120	.200	.180	8	30
30 PER CENT CREAM.				
2	0.117	0.111	15	4
24	.121	.117	12	12
48	.136	.121	10	24
72	.157	.136	9	32
96	.180	.157	8	34
120	.200	.180	7	36

AGE.

Age is an important factor in the whipping of cream. Fresh cream which fails to whip often develops into an excellent whipping cream when aged at a temperature sufficiently low (45° F.) to prevent the rapid formation of acidity. Age in this bulletin refers to time after separation of raw cream and after pasteurization or homogenization of cream undergoing those processes.

Care must be used in aging cream. If the temperature exceeds 50° F. the cream will very likely become sour before the desired effect of the aging takes place. It is also likely to become rancid or develop

off flavors when aged for more than 48 hours, unless under ideal conditions.

The required time for aging varies with the butterfat content and the kind of cream. However, the first 24 hours show the most marked effect upon whipping quality of all cream; and the greatest effect takes place during the first 48 hours, after which the increase in whipping quality is very gradual.

Raw cream.—In the case of raw cream containing a low per cent of butterfat, continued aging improves the whip; for instance, 20 per cent raw cream improves with age until 120 hours old, and 22 to 25 per cent raw cream does not reach the maximum whip until 96 hours old. Cream containing 27 per cent or more of butterfat usually reaches the maximum whipping point after 48 hours of aging and shows no material increase in quality after 72 hours. However, with raw cream containing 22 or more per cent of butterfat a satisfactory

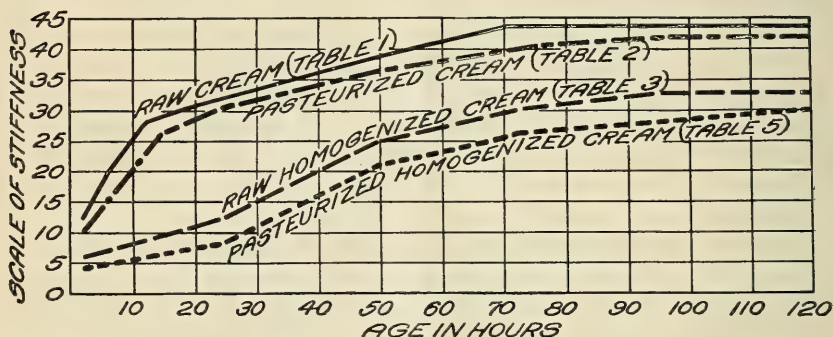


FIG. 11.—Effect of age on whipping quality of 27 per cent cream.

whip can be obtained by aging for 48 hours. (See Table 1 and Fig. 11.)

Pasteurized cream.—A study of Table 2 and Figure 11 reveals the following facts: Twenty per cent pasteurized cream fails to give a satisfactory whip even when aged for 120 hours. Pasteurized cream with a butterfat content ranging from 22 to 27 per cent reaches the maximum whip at 96 hours of age. Thirty per cent pasteurized cream attains its maximum whip when 72 hours old. However, a satisfactory whip can be obtained from pasteurized cream in excess of 22 per cent butterfat at 48 hours of age. The increase in whipping quality which comes from aging longer than 48 hours is gradual.

Homogenized raw cream.—The effect of age upon the whipping quality of cream, homogenized at 3,000 pounds' pressure, is practically the same as upon raw or pasteurized cream. As previously stated, homogenization is very detrimental to the whipping quality of cream, and as a result greater aging is required to obtain the maximum whip. (See Fig. 11 and Table 3.)

Pasteurized-homogenized cream.—The whipping quality of cream homogenized at 3,000 pounds' pressure and pasteurized at 145° F. for 30 minutes is likewise improved by age, as is shown in Table 5 and Figure 11. However, it should be noted that the aging required to obtain the maximum whip is much longer than for raw or pasteurized cream.

BUTTERFAT CONTENT.

Butterfat content has a marked influence upon the whipping qualities of cream (Table 6 and Fig. 12). Increasing the butterfat content up to 30 per cent greatly improves the whipping quality. The work showed that an increase beyond 30 per cent gave no additional improvement in the quality of the whip, but it did give a decrease in the time required to whip.

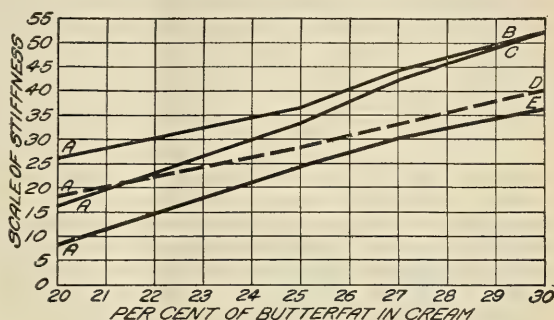


FIG. 12.—Effect of butterfat content on whipping quality of cream. Maximum whips obtained from: A—B, raw cream; A—C, pasteurized cream; A—D, homogenized cream; A—E, homogenized-pasteurized cream.

TABLE 6.—Effect of an increase in butterfat content of cream on whipping quality.

Butterfat content.	Maximum scale reading.			
	Raw cream.	Pasteurized cream.	Homogenized cream.	Pasteurized homogenized cream.
Per cent.				
20	26	16	18	8
22	32	26	28	24
25	36	33	33	30
27	44	42	33	30
30	52	52	40	36

The effect of butterfat content is especially marked in comparatively fresh cream, i. e., 24 hours or less of age. For example, fresh cream with a low butterfat content fails to whip, whereas fresh cream with a 27 per cent or 30 per cent butterfat content, while not giving anywhere near the maximum whip at this age, does give a satisfactory one. (See Table 1.) It is therefore important to consider the butterfat content of cream if it is to be whipped when less than 48 hours old. For whipping purposes no cream containing less than 22 per cent butterfat can be recommended. Although a satisfactory whip can be obtained from 20 per cent raw cream by aging

for 96 hours, there is great danger of it's being off flavor or sour when held for this length of time.

TEMPERATURE.

Temperature plays an important part in whipping cream. As is the case with all other factors affecting whipping quality, temperature has its greatest influence upon cream of low butterfat content. However, the quality of whip from such cream does not improve with a decrease in temperature below 45° F., and with cream containing

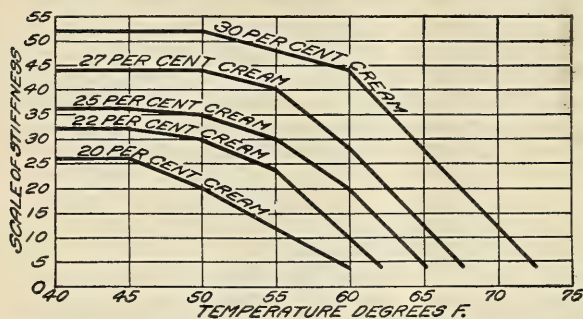


FIG. 13.—Effect of temperature on whipping quality of cream.

27 per cent or more of butterfat does not improve with a decrease in temperature below 50° F.

An increase in temperature above 50° F. causes a decrease in the stiffness of the whip which is in direct ratio to the increase in temperature. Its

effect is such that 20 per cent cream fails to whip at 60°; 22 per cent cream fails at 62°; 25 per cent cream fails at 68°; and 30 per cent cream fails at 72.5°. (See Table 7 and Fig. 13.)

To insure good results, therefore, cream containing a low per cent of butterfat should be whipped at a temperature not greater than 45° F., and cream containing 27 per cent butterfat or more should be whipped at a temperature not exceeding 50° F.

TABLE 7.—Effect of temperature of raw cream on whipping quality.

Temperature.	Scale of stiffness.				
	20 per cent cream.	22 per cent cream.	25 per cent cream.	27 per cent cream.	30 per cent cream.
° F.					
40	26	32	36	44	52
45	26	32	36	44	52
50	20	30	35	44	52
55	12	24	30	40	48
60	4	10	20	28	44
62		4			
65			4	12	28
67.5				4	
70					12
72.5					4

ACIDITY.

It has often been noticed that cream which is several hours old will whip better than fresh cream. Because of this it was believed that the small amount of acidity developed in the cream influenced its whipping equality. Also the idea is prevalent that adding a small amount of commercial lactic acid to the cream improves its whipping quality. In order to compare the effect of acidity with the effect of age, tests were made on cream representing age without acidity, acidity without age, and both age and acidity. The acidity was obtained both by the natural formation of acid and by adding lactic acid.

The maximum acidity which cream may contain without acquiring a sour taste is about 0.3 per cent. It was found that increasing the acidity up to and including 0.3 per cent had no effect upon the quality of the whip. (See Fig. 14 and Table 8.) Increasing the acidity in excess of 0.3 per cent caused a slight decrease in the quality of the

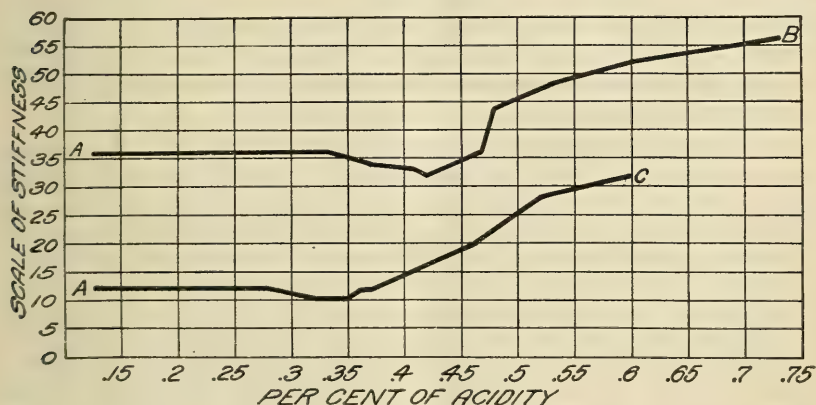


FIG. 14.—Effect of Increase in acidity on whipping quality of cream. A—B, cream which gives a good whip; A—C, cream which gives a very poor whip.

whip until the acidity had increased to such an extent that the cream began to curdle, at which point the whipping quality increases. This was found to be true regardless of whether fresh or aged cream was used.

It is therefore evident that increasing the acidity of cream will not improve its whipping quality, as it is necessary to increase the acidity to such an extent as to render the cream sour before it will have any effect.

TABLE 8.—*Effect of increasing the acidity on whipping quality of good and poor whipping creams.*

Good whipping cream.			Poor whipping cream.		
Acidity.	Time of whipping.	Scale of stiffness.	Acidity.	Time of whipping.	Scale of stiffness.
<i>Per cent.</i>	<i>Minutes.</i>		<i>Per cent.</i>	<i>Minutes.</i>	
0.126	3	36	0.126	5	12
.135	3	36	.135	5	12
.193	3	36	.193	5	12
.234	3	36	.219	5	12
.265	3	36	.265	5	12
.333	3	36	.279	5	12
.373	3	34	.328	5	10
.409	3	33	.346	5	10
.423	3	32	.363	5	12
.468	3	36	.369	5	12
.477	3	44	.419	5	16
.531	3	48	.463	5	20
.603	3	52	.522	5	28
.733	3	56	.607	5	32

VISCOGEN.

The viscogen in these studies was prepared and used according to directions given by Babcock and Russell in Wisconsin Bulletin No. 54, "The Restoration of Consistency of Pasteurized Cream," which are as follows:

Two and one-half parts by weight of a good quality of cane sugar (granulated) are dissolved in 5 parts of water; and 1 part of quicklime gradually slaked in 3 parts of water. This milk of lime should be poured through a wire strainer to remove coarse unslaked particles and then added to the sugar solution. The mixture should be agitated at frequent intervals and after two or three hours allowed to settle until the clear supernatant fluid can be siphoned off.

When properly used, viscogen has a beneficial effect upon the whipping quality of both raw and pasteurized cream. But the increase is not to the extent that an excellent whip should be expected from a poor quality whipping cream. Neither should it be expected that viscogen will give a good whip when other conditions are unfavorable. Viscogen will not overcome the detrimental effect of homogenization.

However, viscogen, on account of its strong alkaline character, must be used with care. Under no circumstances should sufficient quantities be added to render the cream alkaline, for when added to this extent the effect becomes detrimental instead of beneficial. Therefore, before adding viscogen to cream, the amount required to neutralize it should be determined. This can be done by adding phenolphthalein indicator to a known amount of cream and titrating with viscogen. When the amount required to neutralize the cream has been determined, a slightly less quantity of viscogen should be

used. Seldom should more than 1 part by volume of viscogen be added to 100 parts of the cream, and more often 1 part by volume of viscogen to 150 parts of cream is better.

When carefully used in this manner a fair whip can be obtained from cream which would otherwise fail to whip, and a good whip can be obtained from cream which without viscogen gives only a fair whip. In other words, adding viscogen in the proper amount increases the stiffness scale reading from 6 to 16 and from 16 to 28, respectively, of the different creams.

Viscogen should not be added to cream which is to be sold without first consulting Federal, State, and city laws in regard to its use and labeling.

SUGAR.

Adding sugar either before or after whipping cream decreases the stiffness. When added at the rate of 2 teaspoonfuls to 100 c. c. of cream, the decrease in stiffness is 4 points on the scale for each of the different grades of cream. (Table 9.) There is no difference between the effects of granulated sugar and of powdered sugar. Decreasing the amount of sugar decreases the effect until, when added at the rate of 1 teaspoonful to the half pint, it has no effect.

Adding sugar before whipping not only decreases the maximum whip but increases the time of whipping (Table 10), when compared with cream to which sugar has not been added. When compared with cream to which sugar was added after whipping, the stiffness is the same; also when the time required to dissolve the sugar in the whipped cream is taken into consideration, the time of whipping is the same. The results are identical, regardless of whether granulated or powdered sugar is used. If added previous to whipping, there is a certainty that it will be thoroughly dissolved and distributed throughout the cream.

TABLE 9.—Effect of adding sugar¹ after whipping on quality of whipped cream.

Butterfat content.	Time of whipping.	Scale of stiffness.	
		Normal cream.	Cream with sugar added.
<i>Per cent.</i>	<i>Minutes.</i>		
22	6	28	24
25	5	32	28
27	4	40	36
30	3	52	48

¹ Two teaspoonfuls of granulated sugar were added to 100 c. c. of whipped cream, and the cream was whipped for one minute to dissolve the sugar. Confectioner's powdered sugar added, instead of granulated sugar, gave the same results.

TABLE 10.—*Effect of adding sugar¹ before whipping on quality of whipped cream.*

Butterfat content.	Time of whipping.	Scale of stiffness.		
		Normal cream.	Cream with sugar added.	Cream with sugar added and 1 minute longer whipping.
<i>Per cent.</i>	<i>Minutes.</i>			
22	6	28	16	24
25	5	32	22	28
27	4	40	30	36
30	3	52	44	48

¹ Two teaspoonfuls of granulated sugar were added to 100 c. c. of cream before whipping. The experiment was repeated, using the same quantity of powdered sugar, with the same results.

FLAVORING EXTRACT.

Flavoring extract, whether added before or after whipping, affects neither the stiffness of the whip nor the whipping quality. It is preferable to add the extract previous to whipping, as the cream will whip as readily, and time is saved in that the extract is thoroughly mixed through the cream by the time the whipping is completed.

Adding flavoring extract with sugar produces the same effect as though only sugar were added.

“STANDING-UP” QUALITY OF WHIPPED CREAM.

This investigation would not be complete without considering the standing-up quality, or the ability of the whipped cream to retain its stiffness. There are three important and closely related factors affecting the standing-up quality, i. e., temperature, stiffness of the whip, and butterfat content.

If whipped cream could be kept at or below 50° F., it would continue to stand up for several days. With a rise in temperature the stiffness decreases, varying with the increase in temperature and the stiffness of the whip. The effect of a rise in temperature is such that a whip of low quality may become practically useless if allowed to remain at a temperature higher than 65° F. While there is a slight decrease in the stiffness of the better-quality whips with a rise in temperature, it is less marked, and such whips may be held for several hours without falling.

Although an increase in butterfat content beyond 30 per cent does not improve the stiffness of the whip, it does enable the whip to stand up for a longer time and at a temperature that would seriously affect cream with a low butterfat content.

The effect of viscogen upon the standing-up quality is only equivalent to the degree to which it improves the stiffness of the whip.

As previously stated, a satisfactory whip can be obtained from either raw cream with a butterfat content of 20 per cent or more, or from pasteurized cream with a butterfat content in excess of 22 per cent. But because the very purpose for which cream is whipped usually prevents it from being kept at a low temperature, it is recommended that cream for whipping purposes should contain 25 per cent or more butterfat, and that it should be aged for approximately 48 hours before whipping.

WHIPPING QUALITY OF POWDERED CREAM.

Reconstituted cream made from powdered cream and containing as high as 40 per cent butterfat failed to whip. Its whipping quality was not improved by the use of viscogen or by aging. Powdered cream, therefore, may be considered useless for whipping purposes.

WHIPPING QUALITY OF EVAPORATED MILK.

The standard brands of evaporated milk used undiluted whipped but did not stand up. When whipped in the same manner as cream at a low temperature (45° F.) evaporated milk gave a fairly dense whip in from 5 to 7 minutes. But the result is temporary, and if the whip is removed from the ice it returns to its normal condition or consistency in approximately the same time that was required to obtain the whip.

Viscogen added to the extent of 1 per cent failed to improve either the whipping quality or the standing-up quality of the whip. It is therefore evident that evaporated milk is practically valueless for whipping purposes.

SUMMARY.

1. Raw cream excels pasteurized, homogenized, and pasteurized-homogenized cream in whipping quality.

2. Pasteurization is slightly detrimental to the whipping quality of cream, and especially so in the case of cream with a butterfat content below 23 per cent.

3. Homogenization is very detrimental to the whipping quality of cream. The higher the homogenizing pressure the poorer the whipping quality.

4. Homogenizing and pasteurizing combined practically destroy the value of cream for whipping purposes.

5. The whipping quality of cream, regardless of whether the cream contains a high or a low per cent of fat, or whether it is raw, pasteurized, homogenized, or pasteurized-homogenized, is improved by age. However, the age required to obtain a satisfactory whip varies with the kind of cream and the per cent of butterfat. In every case the

most rapid changes occur in the first 48 hours and at 72 hours nearly the maximum whip is obtained.

6. The whipping quality of cream improves with an increase in butterfat content up to 30 per cent, after which the quality of the whip shows no marked increase, but the standing-up quality is improved and there is a decrease in the time required to whip.

7. Temperature is an important factor in the whipping of cream. To insure good results the temperature of the cream should not exceed 45° F.

8. Increasing the acidity, either by adding lactic acid or by allowing the natural formation of acid, does not affect the whipping quality until the acidity content exceeds 0.3 per cent, at which time the cream acquires a sour taste.

9. Viscogen, when properly used, increases the whipping quality of raw or pasteurized cream, and does not affect its flavor.

10. Sugar, when added in quantity sufficient to sweeten thoroughly, decreases the quality of the whip regardless of whether added before or after whipping—the smaller the amount added, the less the effect.

11. Flavoring extract, added in quantity sufficient to flavor, affects neither the whipping quality nor the quality of the whip.

12. Temperature, quality of the whip, and butterfat content are the important factors affecting the standing-up quality of whipped cream.

13. Powdered cream is useless for whipping purposes.

14. Although evaporated milk will whip, it is not useful for whipping purposes because it will not stand up.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1053

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

May, 1922

STUDIES OF CERTAIN FUNGI OF
ECONOMIC IMPORTANCE IN THE
DECAY OF BUILDING TIMBERS

WITH SPECIAL REFERENCE TO THE FACTORS
WHICH FAVOR THEIR DEVELOPMENT
AND DISSEMINATION

By

WALTER H. SNELL, Forest Pathologist
Office of Investigations in Forest Pathology

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BULLETIN No. 1057

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

April 24., 1922

THE CHAULMOOGRA TREE AND SOME
RELATED SPECIES

A SURVEY CONDUCTED IN SIAM,
BURMA, ASSAM, AND BENGAL

By

JOSEPH F. ROCK

Agricultural Explorer, Office of Foreign Seed and Plant Introduction

With an Introductory Chapter by DAVID FAIRCHILD, Agricultural
Explorer in Charge of the Office of Foreign Seed and Plant Introduc-
tion, and a Chapter on the Chemistry of Chaulmoogra, Hydnocarpus,
and Gynocardia Oils by FREDERICK B. POWER, Chemist in Charge
of the Phytochemical Laboratory of the Bureau of Chemistry

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1059

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C.

May 19, 1922

RESEARCH METHODS IN THE STUDY
OF FOREST ENVIRONMENT

By

CARLOS G. BATES, Silviculturist
In Charge Fremont Forest Experiment Station
and
RAPHAEL ZON, Forest Economist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1060

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C.

May, 1922

SITKA SPRUCE
ITS USES, GROWTH, AND MANAGEMENT

By

N. LEROY CARY, Forest Examiner

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1061

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C.

July 29, 1922

LONGLEAF PINE

By

WILBUR R. MATTOON, Forest Examiner

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1064

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. ▼ August 21, 1922

OLEORESIN PRODUCTION

A MICROSCOPIC STUDY OF THE EFFECTS
PRODUCED ON THE WOODY TISSUES OF
SOUTHERN PINES BY DIFFERENT METH-
ODS OF TURPENTINING

By
ELOISE GERRY, Microscopist
Forest Products Laboratory

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1067

Contribution from the Bureau of Public Roads.
THOMAS H. MacDONALD, Chief

Washington, D. C.

PROFESSIONAL PAPER

June, 1922

TESTS OF
DRAINAGE PUMPING PLANTS IN
THE SOUTHERN STATES

By

W. B. GREGORY, Irrigation Engineer

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BULLETIN No. 1068

Contribution from the Office of Farm Management and Farm Economics
G. W. FORSTER, Acting Chief

Washington, D. C.

May 12, 1922

FARM OWNERSHIP AND TENANCY
IN THE BLACK PRAIRIE OF TEXAS

By

J. T. SANDERS

Assistant Agricultural Economist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1074

Washington, D. C.

Issued November 8, 1922; revised August, 1923

CLASSIFICATION OF AMERICAN
WHEAT VARIETIES

By

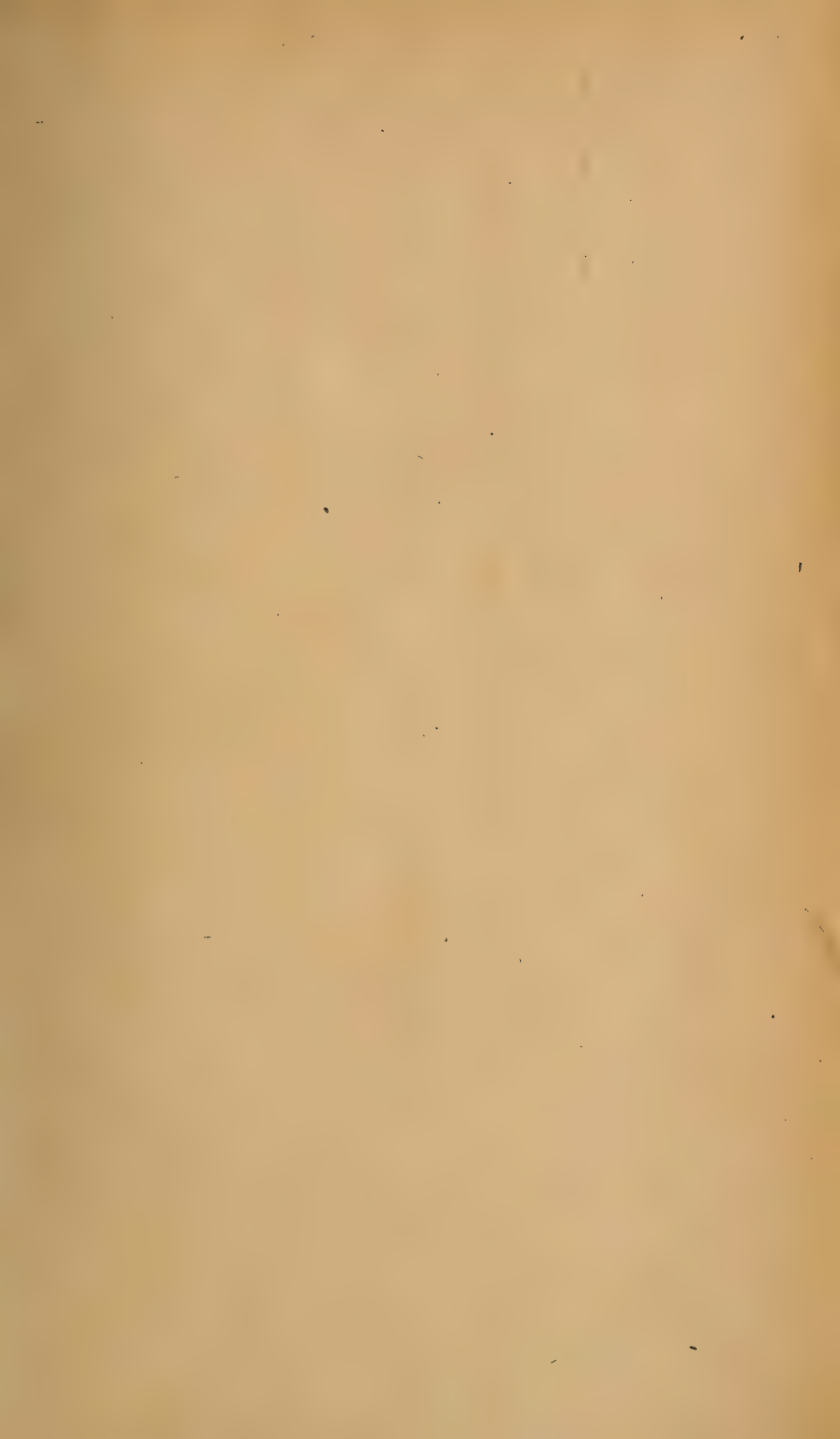
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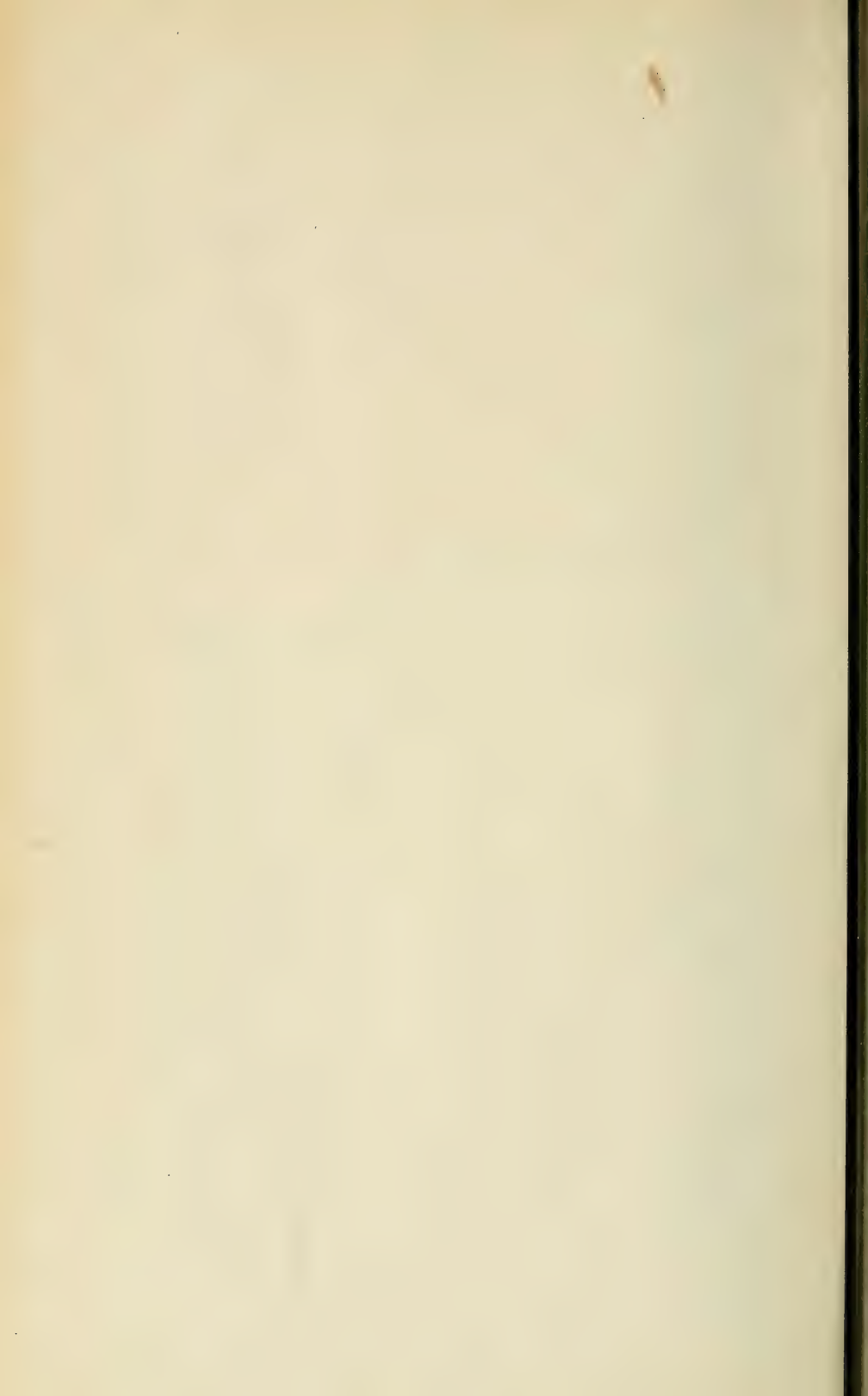
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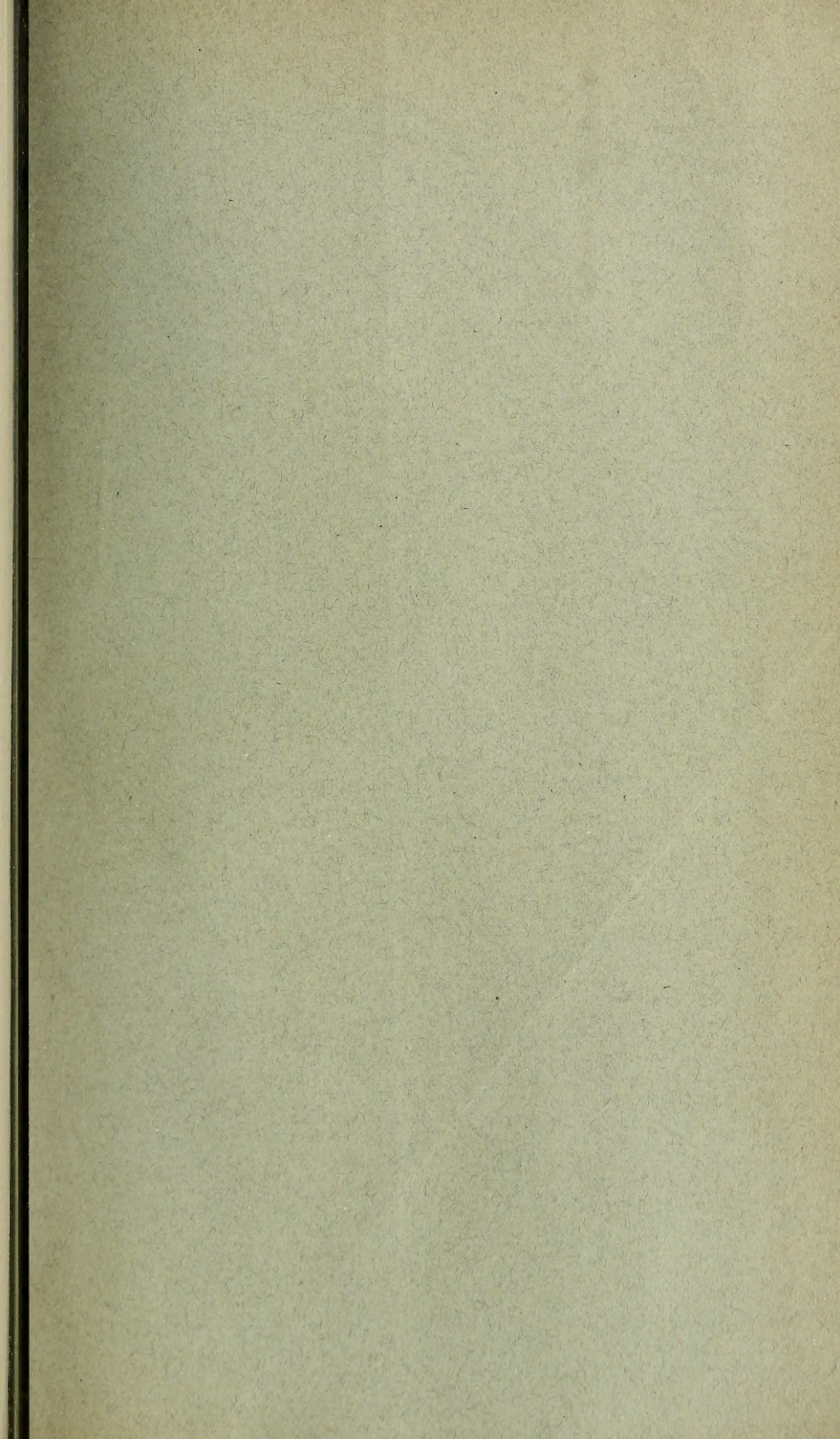
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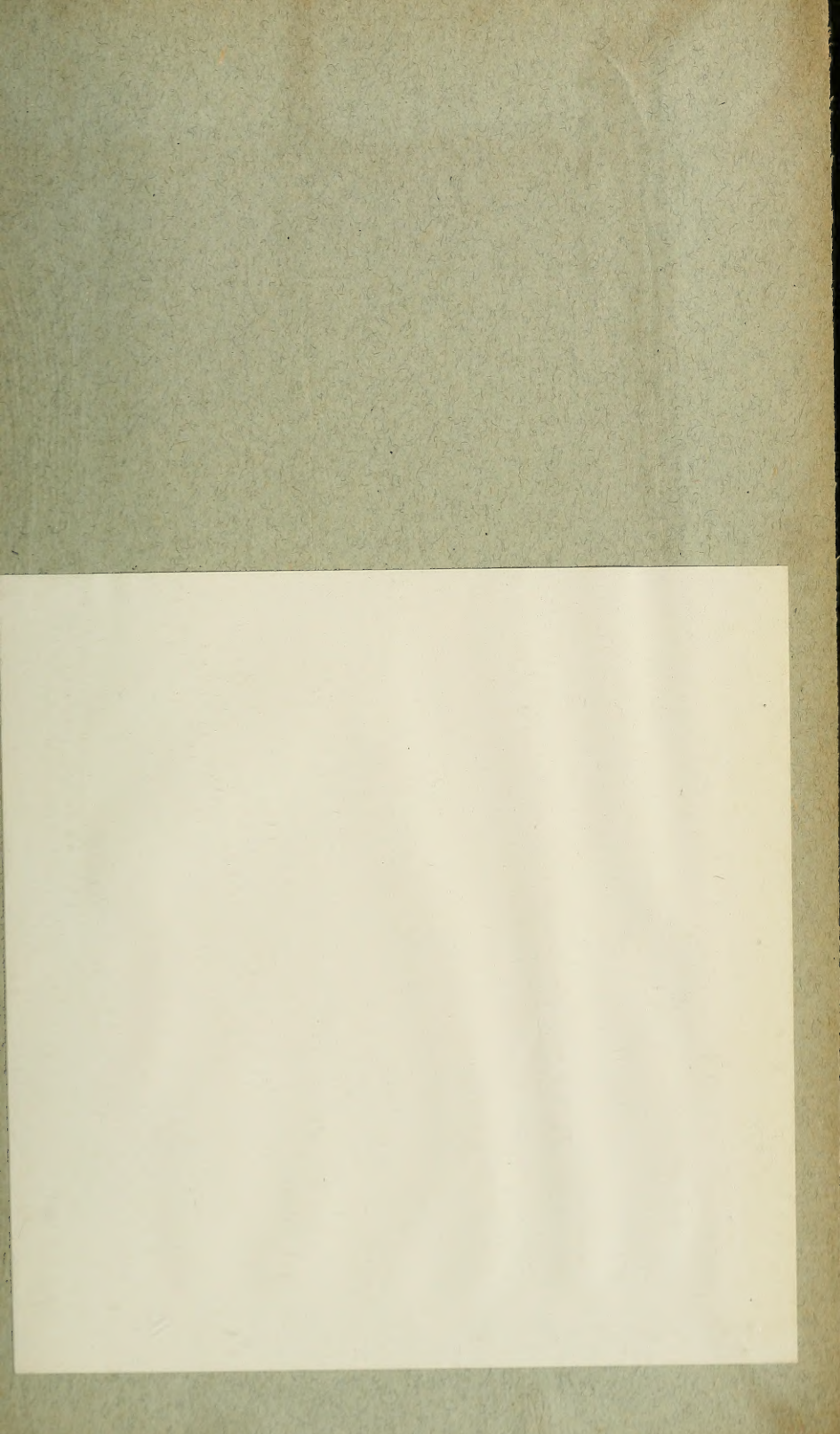












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